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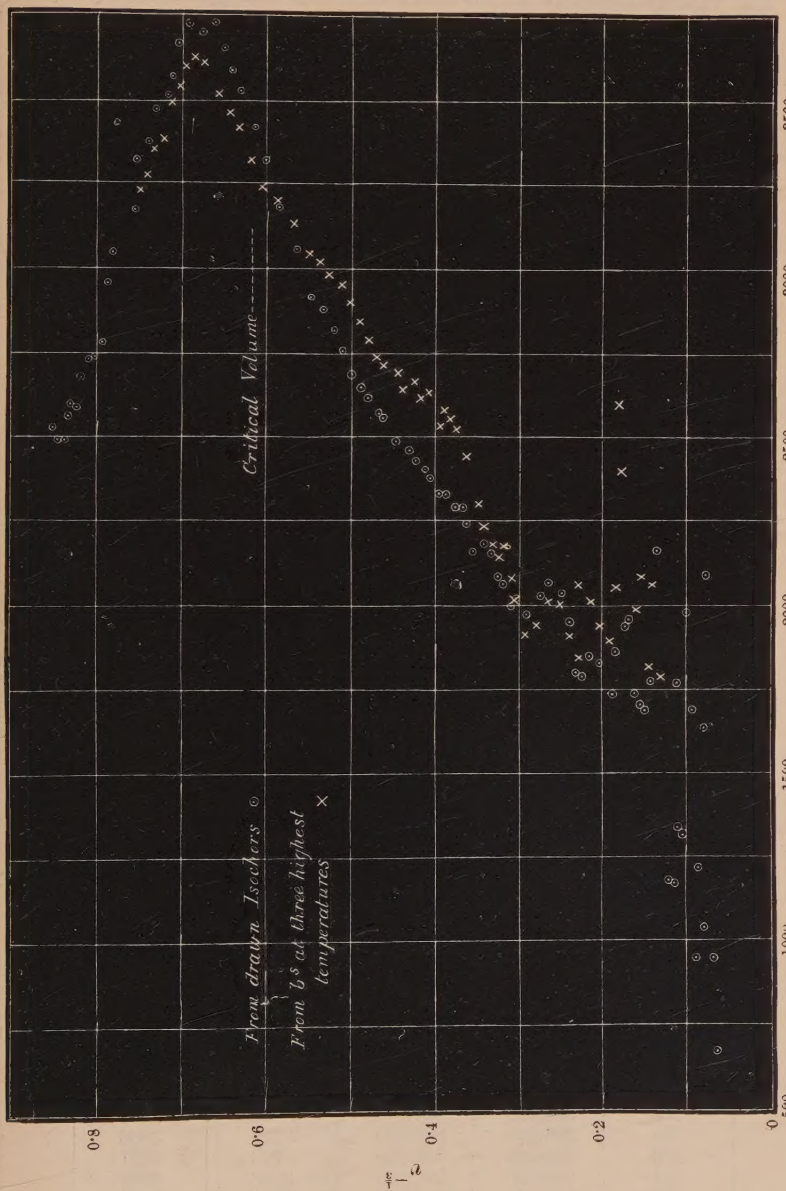

Critical Volume
From drawn Isochors ⊙
From t_3's at three highest temperatures ×
0·8
0·6
0·4
0·2
0
500
1000
1500
2000
2500
3000
3500
$10^{10}/av^2$.
$v^{-\frac{1}{3}}$

the vapour-pressure of mercury becomes too great to allow of accurate observations being made.

The values of a in the equation $p=bT-a$ were ascertained from the drawn isochors, and are given in the table below; also the values of a calculated from those of b derived from the observations at the three highest temperatures. In the latter case, whilst the slope of the isochor depends only on the results obtained at the highest temperatures, the whole of the observations were taken into account in determining its position, and therefore the value of a.

In mapping the values of a it was found best, as suggested by Rose-Innes, to plot $\frac{10^{10}}{av^2}$ against $v^{-\frac{1}{3}}$. The curve is given in fig. 4 (p. 653), and the data in the following table.

It will be seen that a maximum is reached at about volume 3·2, and in this respect also the isopentane results show a strong resemblance to those with ether, the maximum for that substance being at about the same volume.

a.			$\frac{10^{10}}{av^2}$.	
Volume of a gram in cub. centim.	From drawn Isochors.	From b's from three highest temperatures.	From drawn Isochors.	From b's from three highest temperatures.
1·58	1,595,000	.....	2511	.....
1·6	1,566,800	.....	2493	.....
1·65	1,476,000	.....	2489	.....
1·7	1,355,200	.....	2553	.....
1·75	1,252,300	.....	2607	.....
1·8	1.189,000	.....	2596	.....
1·85	1,091,200	.....	2678	.....
1·9	1,017,400	.....	2723	.....
1·95	943,300	.....	2788	.....
2·0	898,400	.....	2783	.....
2·1	768,200	.....	2952	.....
2·2	676,700	.....	3053	.....
2·3	594,300	.....	3181	.....
2·4	521,550	537,640	3329	3229
2·5	471,000	489,930	3397	3266
2·6	425,050	438,550	3480	3373
2·7	389.450	402,590	3522	3407
2·8	355,650	365,010	3586	3494
2·9	324,030	334,850	3670	3551
3·0	298,070	308,120	3728	3606
3·2	263,340	269,700	3708	3621
3·4	231,520	240,200	3736	3601
3·6	209,590	219.230	3682	3520
3·8	190.690	198,930	3632	3481
4·0	175,900	182,310	3553	3428
4·3	157,880	162,890	3426	3320
4·6	142,630	145,690	3313	3244
5·0	125,630	125,150	3184	3196
5·5	107,960	105,650	3062	3129

a.			$10^{10}/av^2$.	
Vol. of gram in c.c.	From drawn Isochors.	From b's fr. 3 highest temps.	From drawn Isochors.	From b's fr. 3 highest temps.
6	93,330	90,940	2976	3055
6·5	82,150	78,160	2881	3028
7	72,485	68,240	2816	2991
7·5	64,560	60,315	2754	2947
8	57,940	54,311	2697	2877
8·5	52,322	48,787	2645	2837
9	47,219	44,599	2615	2768
9·5	42,945	40,452	2580	2739
10	39,001	36,754	2564	2721
11	33,192	30,732	2490	2689
12	28,158	26,590	2466	2612
13	24,310	22,320	2434	2651
14	21,211	19,621	2405	2600
15	18,619	16,998	2386	2615
16	16,790	15,427	2327	2532
17	14,864	13,406	2328	2581
18	13,488	12,120	2288	2547
19	12,073	10,995	2295	2519
20	11,149	10,257	2242	2437
22	9511	8982	2172	2300
24	7912	7597	2194	2285
26	6848	6759	2160	2189
28	6070	5978	2101	2139
30	5345	5114	2079	2173
33	4592	4419	2000	2078
36	3814	3830	2023	2015
40	3174	3284	1969	1903
45	2423	2550	2038	1937
50	1935	1986	2067	2014
60	1358	1388	2046	2001
70	1043	1065	1957	1916
80	874	755	1788	2070
90	693	670	1782	1843
100	542	496	1845	2016
120	381	357	1823	1945
140	292	270	1747	1889
160	210	189	1860	2067
180	160	119	1930	2594
200	128	105	1950	2381
230	109	95	1730	1990
260	87	71	1700	2088
300	66	54	1680	2058
350	46	45	1770	1814
400	29	35·2	2150	1776
500	34·2	.....	1170	.....
600	23 9	.....	1160	.....
700	15·3	.....	1330	.....
800	8·9	.....	1760	.....
900	9 4	.....	1310	.....
1000	8 35	.....	1980	.....
1200	4·1	.....	1690	.....
1400	4·2	.....	1210	.....
1600	4·2	.....	930	.....
1800	1·9	.....	1620	.....
2000	2·4	.....	1040	.....
2300	0·9	.....	2100	.....
2600	0	.....	.....	.....
3000	1·2	.....	930	.....
3500	1·2	.....	680	.....
4000	0	.....	.....	.....

Comparison of Isopentane with other Substances at "Corresponding" Pressures.

The absolute temperatures (boiling-points) and molecular volumes of liquid and saturated vapour were read from the curves at pressures "corresponding" to those adopted in previous papers on this subject (Phil. Mag. Feb. 1892, p. 153; Trans. Chem. Soc. lxiii. p. 1191; Phil. Mag. Jan. 1894, p. 1); and are given in the table below :—

Ratio of Pressure to Critical Pressure.	Pressure.	Absolute Temperature.	Molecular Volume.	
			Liquid.	Saturated Vapour.
	millim.	°	cub. centim.	cub. centim.
·002949	73·8	247·25	.....	.....
·005898	147·5	260·8	.....	.....
·011795	295·1	276·2	112·94	.....
·022411	560·7	292·4	115·86	31040
·044232	1107	312·3	119·84	16380
·088465	2213	336·0	125·24	8490
·14744	3689	356·3	130·68	5180
·20642	5165	371·35	135·50	3675
·29488	7378	388·65	140·29	2540
·44232	11040	410·2	152·93	1614
·58978	14755	426·95	165·15	1132
·73721	18445	440·8	180·35	813·5
·82568	20660	448·0	192·35	671·5
·88465	22130	451·6	204·05	580·0
·94363	23610	457·0	221·65	482·5
·97313	24350	459·1	237·7	425·5
1·00000	25020	460·8	306·5	306·5

The ratios of the absolute temperatures and of the volumes to the critical constants show that isopentane belongs to the same group as benzene and its halogen derivatives, ether, carbon tetrachloride, and stannic chloride. The actual values approach most closely to those of benzene, and for the sake of comparison both are given in the following table (p. 657).

The ratios of the actual to the theoretical densities of the saturated vapour for isopentane and benzene are also given. At the critical point the ratio is 3·73, agreeing very closely with those for the other substances in group I. (3·65 to 3·83) and also with the ratio for carbon dioxide (3·62) deduced from Amagat's observations.

From these results it may be concluded that the molecules of liquid isopentane are simple, like those of the gas.

Errata (p. 650).

Values of $\frac{10000}{bv}$ at { Volume 3·8 *for* 5·507 *read* 5·623; „ 8·5 „ 7·195 „ 7·160; „ 14 „ 8·258 „ 8·241

Ratio of Pressure to Critical Pressure.	Absolute Temperature / Abs. Critical Temperature.		Mol. Vol. of Liquid / Mol. Critical Volume.		Mol. Vol. Sat. Vapour / Mol. Critical Volume.		Actual Density Sat. Vap. / Theoretical Density.	
	Isopentane.	Benzene.	Isopentane.	Benzene.	Isopentane.	Benzene.	Isopentane.	Benzene.
·002949	·5366	·5359	.....	.....	.....	.....	.....	.....
·005898	·5660	·5648	.....	.....	.....	.....	.....	.....
·011795	·5994	·5989	·3685	·3648	.....	.....	.....	.....
·022411	·6346	·6334	·3780	·3742	101·6	.....	1·040	.....
·044232	·6777	·6765	·3910	·3870	53·5	54·4	1·070	1·052
·088465	·7292	·7282	·4086	·4053	27·7	28·2	1·111	1·091
·14744	·7732	·7725	·4263	·4233	16 9	17·25	1·159	1·136
·20642	·8059	·8052	·4421	·4389	12·0	12·35	1·215	1·180
·29488	·8434	·8429	·4636	·4602	8·29	8·49	1·289	1·260
·44232	·8902	·8906	·4989	·4960	5·27	5·35	1·427	1·408
·58978	·9266	·9270	·5388	·5353	3·69	3·72	1·588	1·582
·73721	·9566	·9566	·5884	·5845	2·65	2·69	1·825	1·806
·82568	·9722	·9725	·6275	·6250	2·19	2·20	2·007	2·006
·88465	·9800	·9824	·6656	·6613	1·89	1 91	2·186	2·180
·94363	·9918	·9915	·7232	·7113	1·58	.....	2·488	.....
·97313	·9963	.....	·7755	.....	1·39	.....	2·754	.....
1·00000	1·0000	1·0000	1·0000	1·0000	1·00	1·00	3·73	3·71

LIII. *The Specific Volumes of Isopentane Vapour at Low Pressures.*

By SYDNEY YOUNG, *D.Sc., F.R.S., and* G. L. THOMAS, *B.Sc., University College, Bristol.*

DETERMINATIONS of the volumes of a gram of the unsaturated vapour of isopentane were made in a modified Hofmann's vapour-density apparatus similar in principle to that employed by Ramsay and Young (Phil. Trans. 1887, A. p. 58) in their research on ether.

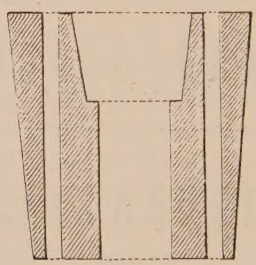
The specimen of isopentane was the same as that used by one of us in the determination of the thermal properties of the substance.

The following alterations were made in the vapour-density apparatus :—

1. A narrow tube A' (fig. 1) was sealed to the large volume tube A in order that the perforation through the indiarubber cork B might be diminished in diameter.

2. The tube was graduated throughout its entire length in millims., and the readings of both columns of mercury were taken directly on the tube, whereas formerly a graduated mirror-scale, placed behind the vapour-density tube, was employed. The direct method of reading was found to be far more convenient and was probably rather more accurate.

Fig. 2.



3. The small mercury-trough used for inserting the vapour-density tube in the apparatus was cut in the indiarubber cork as indicated in fig. 2, which represents a vertical section through the cork.

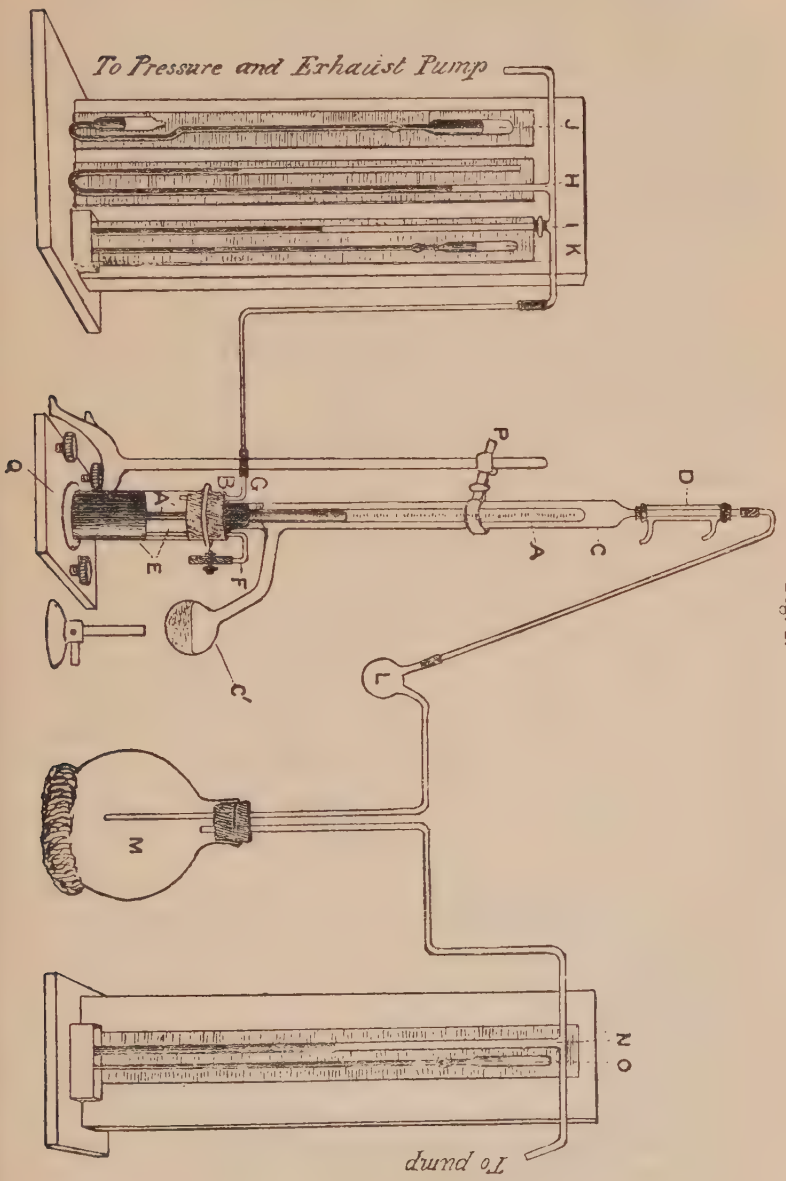


Fig. 1.

4. The vapour-density tube is supported only by the india-rubber cork through which it passes, and there was previously some little trouble in keeping the tube vertical, and at the same time accurately centred in the outer jacketing-tube C (fig. 1). This difficulty was overcome by placing the apparatus on a stand Q provided with three screwed feet. The jacketing-tube was supported by a clamp and large retort-stand P and was made vertical once for all; the vapour-density tube was then easily centred by means of the screwed feet.

As it was important to take readings over as wide a range of pressure and volume as possible, the atmospheric pressure on the mercury in the large glass jar E was not only lowered but raised. A differential gauge H was therefore employed in addition to the ordinary gauge I, shown in the diagram previously published (*loc. cit.*).

When the pressure in E was high there was danger of the large indiarubber cork being forced up, and it was therefore held in position by the following arrangement:—Two pieces of wood, notched near the ends, were laid on the cork between the jacketing tube and the small tubes F and G. A stout piece of copper wire was fastened round the glass jar under the flange at the top, the glass being protected by a strip of sheet indiarubber. Two pieces of copper wire of smaller diameter were then passed round the pieces of wood and the stouter wire, and the pressure on the pieces of wood was increased to the required amount by twisting the wires.

The whole apparatus—with the exception of the two pumps and the arrangement for keeping the large indiarubber cork in position—is shown in fig. 1, and is explained below:—

AA′. The vapour-density tube.

B. The large indiarubber cork.

CC′. The jacketing-tube provided with the condenser D.

E. The glass jar in which the atmospheric pressure is altered.

F. Narrow glass tube dipping below the surface of the mercury in the jar and used for removal of mercury after insertion of the vapour-density tube.

G. Narrow glass tube passing just through the indiarubber cork and connected by lead or glass tubing with

HI the differential and ordinary gauges.

JK. Barometers.

L. Small bulb to collect any of the jacketing substance not condensed at D. It occasionally happens that a little carbon bisulphide or alcohol, when boiling under reduced pressure, escapes condensation at D.

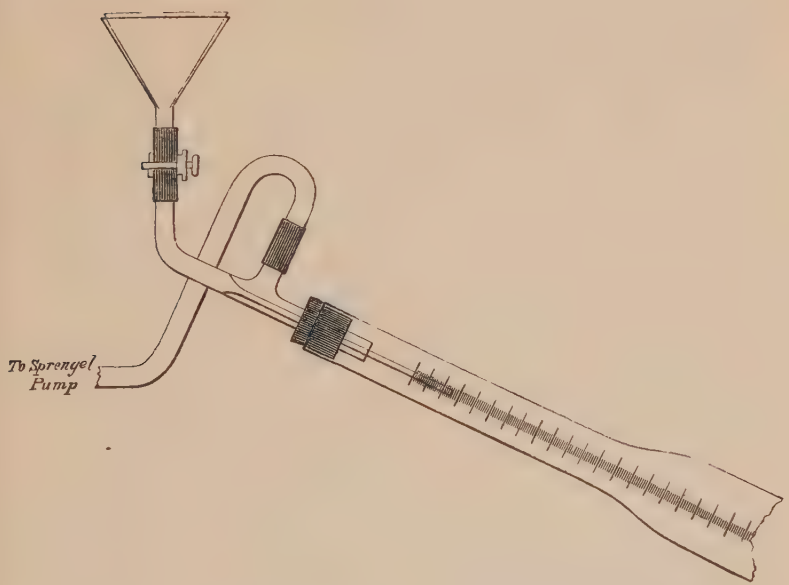
M. A large air-reservoir to prevent oscillation of the mercury columns in the gauge N.

NO. Gauge and barometer for measuring the pressure under which the liquid in the bulb C′ is boiling.

P. Retort-stand and clamp to support the jacketing-tube.

Q. Wooden stand with three screws to centre the vapour-density tube.

Fig. 3.



In order to avoid the presence of air in the vapour-density tube it was filled with mercury in the manner indicated in the diagram (fig. 3). The tube was thoroughly exhausted by means of a Sprengel pump, and was heated to remove the

film of air adhering to the glass. Filtered mercury was then run slowly into the tube, the Sprengel pump being kept constantly in action and the tube hot until it was nearly filled*. After cooling, the vapour-density tube was removed, a little more mercury added so as to completely fill it, and it was then inverted in a large trough of mercury. The isopentane was weighed in a small bulb (fig. 4) provided with a hooked capillary neck, and the bulb was passed up into the tube immediately after being weighed.

Fig. 4.

The evaporation from the capillary tube is extremely slow if the temperature is sufficiently below the boiling-point of the liquid, but with such a volatile substance as isopentane it is advisable to choose a cool day. That no sensible loss by evaporation was taking place was proved by the fact that the difference of reading for 1 mgrm. (by the method of oscillations) was the same for the empty bulb as for the bulb filled with isopentane.

The hook on the capillary tube is convenient for manipulation, but the bulb should be inserted in the vapour-density tube with the hook upwards, otherwise it may be caught at the bottom of the tube. This, in fact, actually happened with the second quantity, and it was necessary to disengage the bulb with the finger. In all probability the bulb was in this case slightly warmed and a small quantity of isopentane escaped owing to the expansion of the liquid. The weight was therefore calculated by comparison of the volumes of vapour with those of the first and larger quantity at the same temperatures and pressures. There appeared to have been a slight loss, for the mass of isopentane determined by direct weighing was 0·0376 gram, whilst that calculated from the comparison of volumes was 0·0373 gram.

The pressures of the isopentane vapour require to be corrected for the heated column of mercury, and also at the higher temperatures for the vapour-pressure of mercury. The first correction is necessarily uncertain, as it is impossible

* All the indiarubber tubes and corks with which the mercury could come in contact had been boiled with strong potash.

to decide exactly how far down the tube the mercury is heated. It was assumed that its temperature was that of the jacketing vapour down to 1 centim. below the surface of the condensed liquid in the jacketing-tube. The error involved is extremely small at the lower temperatures, but increases with rise of temperature. The readings with the larger quantity of substance were therefore taken only to 150° and with the smaller quantity to 100°.

The data obtained are given in the following table; the mass of the larger quantity of isopentane, obtained by direct weighing, was 0·1290 gram, that of the smaller quantity was 0·0373 gram. The value of $\frac{PV}{T}$, taking the molecular weight of isopentane as 71·85 and the weight of a litre of hydrogen at 0° and 760 millim. as 0·0899 gram, would be 862.

Series I.

Temp.	Pressure. millims.	Volume. cub. cms.	$\frac{PV}{T}$.	Temp.	Pressure. millims.	Volume. cub. cms.	$\frac{PV}{T}$.
10°·75	190·8	1273·0	856·1	40° ...	443·2	597·1	845·5
	206·8	1169·5	852·7	(*cont.*)	517·9	508·6	841·5
	226·5	1066·5	851·4		610·4	429·2	837·0
	250·6	962·3	850·0		757·7	343·1	830·5
	279·6	861·5	849·0				
	318·7	753·3	846·2	50° ...	219·7	1257·0	855·1
	359·1	666·5	843·7		239·2	1153·5	854·2
	390·9	610·8	841·7		262·6	1050·0	853·7
30° ...	211·1	1230·5	857·2		293·8	935·7	852·7
	228·2	1133·5	853·9		327·2	841·0	851·9
	250·7	1032·5	854·1		372·8	736·6	850·2
	278·3	928·2	852·6		432·0	632·3	845·6
	291·1	886·3	851·5		510·6	533·7	843·7
	326·8	787·8	849·7		607·2	446·2	838·9
	375 1	684·2	847·0		733·8	367·1	834·1
	437·6	584·3	843·9				
	530·0	479·7	839·0	60° ...	233·4	1222·5	856·9
	654·5	385·5	832·7		254·7	1119·0	856·1
	755·2	331·6	826·4		280·3	1015·5	854·6
					312·6	909·7	854·0
40° ...	219·1	1224·0	856·8		351·9	806·8	852·6
	239·3	1118·5	855·0		402·3	702·9	849·2
	263·5	1014·5	854·0		471·7	597·9	847·0
	291·0	916·8	852·4		567·9	491·9	844·0
	330·4	805·7	850·5		683·9	408·7	839·4
	378·7	701·9	849·2		790·2	351·8	834·8

Series I. (*continued*).

Temp.	Pressure millims.	Volume. cub. cms.	$\frac{PV}{T}$.	Temp.	Pressure millims.	Volume. cub. cms.	$\frac{PV}{T}$.
70° ...	240·8	1222·0	857·8	110°...	514·9	633·4	851·5
	262·1	1119·0	855·2	(*cont.*)	593·2	549·7	851·4
	288·8	1015·0	854·8		698·1	465·5	848·5
	318·8	919·5	854·6		849·6	380·4	843·9
	355·0	824·1	853·0				
	405·3	720·1	850·9	120°...	275·2	1224·5	857·4
	472·0	616·0	847·7		300·6	1120·5	857·2
	565·7	512·4	845·1		325·7	1034·1	857·0
	675·8	427·0	841·2		356·4	945·1	857·1
	789·2	363·7	836·8		391·4	859·5	856·0
					435·7	772·1	856·2
80° ...	247·2	1222·0	855·8		489·3	685·5	853·5
	269·9	1119·5	855·8		558·3	600·4	853·3
	297·3	1015·5	855·3		653·0	512·9	852·2
	325·6	927·2	855·2		753·1	442·5	848·0
	365·3	823·9	852·6		868·6	382·8	846·1
	417·1	720·2	850·9				
	486·4	616·1	849·0	130°...	282·2	1224·5	857·5
	564·0	529·9	846·7		303·7	1138·5	857·8
	669·3	444·5	842·8		328·8	1051·5	857·9
	798·2	370·8	838·5		362·4	954·0	857·9
					393·2	877·0	856·3
90° ...	254·4	1222·5	856·9		435·9	791·8	856·5
	277·5	1119·5	855·8		490·3	703·5	855·9
	305·7	1016·0	855·5		558·3	616·5	854·0
	334·9	926·9	855·2		646·3	531·1	851·8
	375·6	824·3	852·9		746·0	459·7	850·9
	429·2	720·2	851·5		872·1	391·6	847·4
	500·8	615·6	849·3	140°...	293·7	1206·5	858·1
	580·1	530·1	847·1		311·5	1138·5	858·7
	689·5	444·6	844·5		336·9	1023·0	857·9
	815·6	374·0	840·4		367·1	966·4	859·0
					404·2	877·2	858·5
100°...	261·3	1223·5	857·0		447·9	790·5	857·3
	285·3	1120·0	856·8		502·6	703·8	856·5
	314·1	1016·0	855·6		571·2	618·5	855·4
	341·2	935·2	855·5		663·6	531·3	853·7
	386·2	824·8	853·9		762·9	461·0	851·6
	441·5	720·0	852·2		899·1	390·0	849·0
	501·3	633·3	851·1				
	578·4	547·5	849·0	150°...	300·4	1208·5	858·2
	684·0	461·9	847·0		319·3	1138·0	859·0
	825·1	380·5	841·7		345·4	1052·5	859·2
					371·7	977·4	858·9
110°...	268·6	1224·5	858·7		413·4	877·4	859·5
	293·2	1120·5	857·8		459·7	790·6	859·1
	317·5	1034·0	857·0		513·8	705·9	857·4
	350·6	935·6	856·4		586·9	618·1	857·6
	397·4	824·7	855·7		682·3	530·4	855·6
	454·2	720·2	854·0		783·8	460·3	852·9
					912·5	394·2	850·4

Series II.

Temp.	Pressure. millims.	Volume. cub. cms.	$\frac{PV}{T}$.	Temp.	Pressure. millims.	Volume. cub. cms.	$\frac{PV}{T}$.
11°·0	60·7	4045	864	60°...	70 8	4044	860
	66·6	3685	864		77·8	3697	864
	73·6	3326	862		86·5	3336	867
	82·8	2965	865		96·9	2968	864
	93·7	2606	860		109·9	2607	861
	108·6	2246	859		127·3	2253	861
	129·0	1888	857		151·2	1892	859
	158·9	1529	856		187·5	1525	858
	205·7	1176	852		242·9	1171	858
	287·5	837	847		285·5	995	853
					349·0	812	851
16°·3	61·8	4044	864				
	67·8	3686	864	70°...	73 4	4046	866
	75·2	3324	864		80·6	3687	866
	84·0	2965	861		89·1	3331	865
	95·5	2607	860		99 8	2971	864
	110·7	2245	859		113·5	2608	863
	131·7	1883	857		131·4	2249	862
	163·4	1516	856		155·6	1894	859
	209·5	1178	853		192·2	1531	858
	298·3	821	847		249·0	1177	855
	451·8	536	837		292·1	1004	855
					356·6	1817	850
30°...	64·6	4047	863				
	70·8	3691	862	80°...	75·5	4042	865
	78·9	3331	867		82·6	3694	864
	88·0	2968	862		91·8	3338	868
	100·5	2602	863		103·0	2968	866
	116·0	2249	861		116·6	2614	864
	138·2	1882	859		134·8	2254	861
	170·1	1526	857		160·5	1889	859
	221·0	1171	854		196·7	1543	860
	257·2	1006	854		257·7	1172	856
	315·2	816	849		304·6	991	855
					364·8	824	851
40°...	66·8	4048	864				
	73·4	3688	865	90°...	77·4	4053	864
	81·6	3325	867		85·1	3696	867
	91·3	2969	866		94·6	3329	868
	103·8	2606	864		106·0	2976	869
	120·0	2245	861		120·4	2605	864
	142·7	1888	861		139·2	2248	862
	175·5	1528	857		165·7	1888	862
	228·3	1172	854		203·0	1540	861
	266·6	1000	852		266·6	1170	859
	322·7	823	849		312·8	994	857
					378·9	818	854
50°...	69·0	4050	865				
	75·6	3694	865	100°...	79·4	4048	862
	84·1	3335	866		87·4	3692	865
	93·9	2970	864		97·2	3340	870
	107·1	2602	863		109·1	2967	868
	123·8	2247	861		123·8	2610	866
	146·8	1895	861		142·6	2257	863
	180·4	1537	858		170·9	1884	863
	235·7	1171	855		208·9	1539	862
	276·1	999	854		271·6	1180	859
	333·4	825	851		321·5	995	858
					392·6	813	855

LIV. *Isopentane from Amyl Iodide.* *By* SYDNEY YOUNG, *D.Sc., F.R.S., and* G. L. THOMAS, *B.Sc., University College, Bristol.*

ISOPENTANE has been prepared from amyl iodide by Frankland (Trans. Chem. Soc. iii. pp. 31 and 481) by the action of zinc and water, and by Just (*Annalen*, ccxx. p. 146) by the action of zinc and hydrochloric acid.

Frankland gives the boiling-point of his specimen of isopentane as 30° under a pressure of 734 millim., and Just as 30° under the normal pressure. These boiling-points are considerably higher than that of the isopentane employed in the researches described in the accompanying papers.

The specific gravities observed by Frankland and by Just are also much higher than any others recorded. On the other hand, Mr. J. W. Rodger informs us that he has prepared specimens of isopentane from amyl iodide made from Scotch and Irish amyl alcohol, and that the boiling-point in each case was almost exactly 28°.

As it was of importance to obtain every possible proof of the purity of the isopentane employed for the determination of the physical constants of that substance, we thought it advisable to compare its properties with those of a specimen prepared from amyl iodide. The iodide was obtained from Burgoyne & Co.; it boiled within moderate limits of temperature, and it was not thought necessary to fractionate it.

The replacement of the iodine by hydrogen was effected in two different ways:—(*a*) by the action of the zinc-copper couple on a strong alcoholic solution; (*b*) by the slow addition of very strong hydrochloric acid to amyl iodide, dissolved in a large quantity of alcohol, in presence of zinc slightly covered with copper.

In the first case zinc-foil was employed, and the couple was prepared by the method recommended by Gladstone and Tribe (Trans. Chem. Soc. xlv. p. 154); it was thoroughly washed with water, and finally twice with alcohol. The amyl iodide, dissolved in rather more than its own volume of

absolute alcohol, was added and then a few drops of hydrochloric acid. The flask containing the mixture was provided with a reversed condenser and a glass tube, bent twice at right angles, the end of which dipped under mercury.

The action at the temperature of the room (about 10°) was slow, for after forty hours, when a few drops of the liquid were added to water, the oil which separated sank to the bottom. Some isopentane, however, had been formed, and it was distilled off and collected. The remainder of the alcoholic solution of amyl iodide was then subjected to the action of the zinc-copper couple for twenty hours at a temperature of from 30° to 35°. The alcoholic solution of isopentane was then distilled from the flask containing the couple, and the distillate was shaken several times with water to remove alcohol. A considerable amount of amylene was present, and bromine was therefore added until the isopentane remained permanently coloured. The excess of bromine was removed with caustic soda, and the isopentane was washed with water, dried with calcium chloride, and distilled. The temperature rose from 27°·5 to about 50°, when the distillation was stopped, a considerable amount of amylene dibromide being left in the flask. The quantity of crude isopentane was too small to allow of satisfactory fractionation, and it was therefore mixed with the substance obtained by the other method.

The remainder of the amyl iodide was treated by the method described by Just (*loc. cit.*) except that the zinc, after purification with dilute acid, was treated once with a 2-per-cent. solution of copper sulphate. The action was evidently greatly accelerated by the presence of the copper, for Just states that the conversion was not complete until after 9 or 10 days, whereas we found that very little iodide was left after less than 24 hours.

The amyl iodide, dissolved in five times its volume of absolute alcohol, was added to the zinc-copper couple in a flask cooled by ice, and the hydrochloric acid (obtained by saturating the pure concentrated acid, cooled by water, with the gas) was added drop by drop from a separating funnel. A reversed condenser was, of course, unnecessary, as the temperature was maintained at 0°, but the flask was provided with a glass tube bent twice at right angles and dipping under

mercury. It was found that the evolution of hydrogen was not great until the reduction of the iodide was nearly complete.

After about 24 hours it was found that when a few drops of the alcoholic solution were added to water, a light liquid separated and floated on the water. The solution was then poured away from the zinc and was distilled from the water-bath until, on addition of a small quantity of the distillate to water, no further separation of isopentane took place.

The distillate was shaken several times with water to remove alcohol, and was treated in the same manner as the isopentane obtained by the other method. In this case, however, it was found that the amount of bromine required to remove the amylene was very much smaller, and also that the yield of isopentane was better.

The two quantities of isopentane were mixed together and, after being distilled from phosphorus pentoxide, were fractionated eight times from a distillation-bulb with a long still-head. A fair quantity of substance, boiling quite constantly at 27°·6 under a pressure of 750·6 millim., was obtained.

The isopentane was subsequently distilled on four occasions from phosphorus pentoxide, and the observed boiling-points are given below:—

Pressure.	Temperature.	Corrected to 760 millim.
750·6	27·6	27·95
753·2	27·7	27·95
751·8	27·65	27·95
768·0	28·2	27·9
	Mean	27·95

The mean boiling-point is identical with that of the specimen prepared from Kahlbaum's "pentane." The specific gravity was determined at 0° and 13°·4 in the modified Sprengel tube, with the following results :—

Sp. gr. at 0°... 0·63935 ; at 13°·4... 0·62632.

The mean specific gravity at 0° of the other sample was 0·63924.

The vapour-pressures and the volumes of a gram of liquid and saturated vapour were determined at three temperatures,

and a few volumes and pressures also at the critical temperature. The results are given in the following table and, for the sake of comparison, those obtained under similar conditions with the other specimen of isopentane are added.

It will be seen that the agreement is satisfactory, and additional evidence is thus afforded of the purity of the substance.

The observed critical temperature was 187°·8 (the substance being heated with aniline vapour under increased pressure). This is identical with the mean temperature observed with the sample from Kahlbaum's "pentane."

Temperature.	*Isopentane from Amyl Iodide.*	*"Pentane" from Kahlbaum.*
	Vapour Pressure.	
160°	16316	16323
170°	19117	19115
180°	22270	22270

Volumes of a Gram.

	Liquid.	Saturated Vapour.	Liquid.	Saturated Vapour.
160° ...	2·3745	13·70	2·3775	13·71
170° ...	2·5545	10·73	2·5550	10·73
180° ...	2·8560	7·943	2·8590	7·952

Critical Isothermal.

	Volume.	Pressure.	
187°·8 ...	3·067	26060	26040
	3·268	25350	25310
	3·468	25120	25070
	3·871	25040	25030
	4·276	25020	25010
	4·679	25040	25000
	5·086	25020	24990
	5·493	24980	24960
	5·902	24880	24870
	6·306	24740	24730

LV. *The Gladstone "Law" in Physical Optics, and the True Volume of Liquid Matter.* *By* WALTER HIBBERT, *F.I.C.*

ONE of the curious results established in Chemical Optics is that two independent formulæ (those of Gladstone and Lorentz respectively) can be used in the discussion of experimental data relating to the refractive index and the density of a given substance. Neither of them can claim any special advantage. They both have a wide range of application, yet neither holds universally good. Still more curiously, they break down under quite different conditions of experiment.

The Lorentz formula,

$$\frac{\mu^2-1}{\mu^2+2}\cdot\frac{1}{d}=\text{constant},$$

which is able to cover the large variation in density separating a liquid and its vapour, gives erroneous results in the simple case of a liquid whose density is changed by pressure. On the other hand, the Gladstone formula,

$$\frac{\mu-1}{d}=\text{constant},$$

is unique in its power to deal with liquids under varying pressure, but fails in the jump from liquid to vapour.

Hitherto no light has been thrown on these anomalies, but this present paper attempts to explain the exceptions in the case of the Gladstone expression, and, incidentally, introduces a physical magnitude which is conveniently described as the "actual volume occupied by one gramme of the substance."

The suggestion of the present argument arose out of a number of experiments carried out by Dr. Gladstone and myself during the last two years. We have examined a great variety of salt-solutions, whose strength varied from saturation down to about 5 per cent.—a dilution limit imposed by experimental error when the hollow-prism method is adopted for obtaining the refractive index.

Our main conclusion, to the effect that the value of $\frac{\mu-1}{d}$ for the salt is practically constant, has received special confirmation by the publication of a paper by Kohlrausch and Hallwachs*, in which they extend the work on about 10 salts to extremely dilute solutions. They used an interference method for determining μ, and a special apparatus for getting d with the necessary accuracy, so that the experimental error is not larger than usual, even when the amount of salt present is not greater than 0·05 per cent. of the solution.

An examination of this body of evidence proved to me that the constancy of $\mu-1/d$ was much greater for an ordinary dissolved salt than for a simple liquid whose density is changed by heat. For example:—

When heptane is heated from 12° to 88° its density changes by about 10 per cent., and the value of $\mu-1/d$ by 0·55 per cent.

Sodium chloride, diluted from 13 per cent. down to 0·03 per cent. (a concentration change of 400 to 1), has its value for $\mu-1/d$ changed by 0·22 per cent. only.

In speculating on this far greater constancy in the case of a dissolved salt, it seemed not unreasonable to regard the solution in the light of Van't Hoff's theory, attributing a pseudo-gaseous condition to the dissolved salt. This at once suggested other comparisons, and led to the following summary statement of all experimental results on the subject:—

1. The Gladstone expression is true in the case of gases whose density is changed by varying pressure†.

2. It is true in the case of liquids whose density is changed by varying pressure‡.

3. It is true (or a *very* close approximation) in the case of dissolved salts, especially in dilute solution.

4. It is a less close approximation in the case of simple liquids undergoing thermal expansion.

5. It altogether fails when a liquid is changed into vapour.

* Wied. *Ann.* 1894, liii. p. 1.

† Biot and Arago, *Mém. d. l'Inst.* vii. p. 301 (1806), and Chappuis and Rivière, *Compt. Rend.* ciii. Biot and Arago express their results $(\mu^2-1)v=\text{const.}$ But μ^2 is only slightly greater than unity, and therefore $(\mu-1)v$ must also be constant.

‡ Quincke, Phil. Mag. 1884, xvii. p. 65.

On studying the results included in 4, it appeared that they had one point in common. If the variation be expressed in symbols, it may be put in the form

$$e_t = e_0(1 \pm at),$$

where e_0 and e_t are the values of $\frac{\mu-1}{d}$ at 0° and $t°$ respectively. Examination showed that all good experiments gave a negative sign for the coefficient a. In other words, the value of e always diminishes as the density diminishes. If we put $(\mu-1)/d=(\mu-1)v$, where v is the volume of unit mass, we may say that $(\mu-1)v$ always diminishes as v increases. This statement is still more emphatically true when the liquid becomes a vapour.

Therefore, in classes 4 and 5, whenever v increases the product $(\mu-1)v$ diminishes. In liquids, where the change in v is not very great, the diminution of the product is small; but in passing to vapour, where the change in v is enormous, the product $(\mu-1)v$ undergoes a large diminution. To put the same thing in the inverse sense, the results show that when v becomes comparatively small, there is a marked increase in the product. So stated, they afford criteria by which we may possibly find the cause of the deficiency. The conditions are almost a reproduction of those which led to the second approximation in the case of Boyle's law. Experiment showed that the product pv was only constant when v was comparatively large. As v diminished, there was a tendency for the product to increase, and it became necessary to suppose that the expression pv referred not to the whole space symbolized by v, but to v minus the space occupied by the particles. Hence $p(v-b)$, where b is the actual volume of the matter, has taken the place of pv.

It appeared to me, that the similar experimental results would warrant the introduction of a similar symbol in the Gladstone expression, thus transforming it into

$$(\mu-1)(v-\beta) = \text{constant}.$$

It is at once apparent that the introduction of β tends to remove the anomalies, and also evident why cases 1, 2, and 3 in the above summary are satisfied by the uncorrected formulæ.

In 1 and 3, that is in the case of gases and dissolved salts respectively, the value β is negligible compared with v.

In 2, owing to the very slight compressibility of the liquids, the changes in v are always exceedingly small. Hence $v-\beta$ will change almost as much as v, if, as is probable, β is not a large fraction of v.

In 4, the case of liquids undergoing thermal expansion, the changes in v are great enough, as compared with the value of β, to cause an appreciable difference between the ratios v/v_1 and $(v-\beta)/(v_1-\beta)$.

In 5, the case of vaporization, we have v for the liquid comparatively small, changing into a very large value in the vapour. Here there is a decided and altogether disturbing difference between the ratios v/v_1 and $(v-\beta)/(v_1-\beta)$*.

Evidently, then, if the numerical data are found to be of the right order, the introduction of β will remove the reservations with which the Gladstone law is usually stated. Moreover, the physical conditions under which β needs to be introduced render it probable that β has, or may have, a physical meaning, and is not merely of the nature of an arbitrary constant. But the real justification for introducing β must be, *à posteriori*, by showing that the calculated values are not improbable, and that they have relations to other physical quantities.

We can determine β for any one substance from observations on a liquid at two different temperatures.

Let μ_1, μ_2 be the refractive indices; v_1, v_2 the volumes of

* This paper was written out before I recalled the fact that Ketteler suggested the same solution for the discrepancies experienced in applying the expression $(\mu^2-1)v=$constant. Writing it $(\mu^2-1)(v-\beta)$ he examined a series of experiments made by Weegmann (*Zeit. phys. Chem.* ii. p. 905). The result was not very encouraging. But I am of opinion that there are two reasons for that discouragement. First, Weegmann happened to work on substances of exceptional density, a fact which ought to foreshadow the probability of exceptional results in any volume deduced from them. Secondly, the expression $(\mu^2-1)v$ is surely not so good a basis for the investigation as the simpler one due to Gladstone and Dale. In ordinary liquids it is not so constant; it is not supported by Quincke's experiments on liquids under pressure (*comp.* Sutherland, Phil. Mag. 1888); nor does it render such service in Physical Chemistry as either the Gladstone or Lorentz expression.

unit mass $\left(=\frac{1}{d}\right)$ at the temperatures of two experiments, and let β have the meaning suggested, then

$$(\mu_1-1)(v_1-\beta)=(\mu_2-1)(v_2-\beta),$$

and

$$\beta=\frac{(\mu_1-1)v_1-(\mu_2-1)v_2}{\mu_1-\mu_2}.$$

This equation shows that the measure of β will depend on differences which we know to be small, and it is at once evident that the best experiments only will be serviceable. Thus, a table of results for carbon disulphide gives the following figures for the temperatures of 0° and 40° Centigrade ; the data are Ketteler's :—

$$\mu_1=1{\cdot}64375,\ \mu_2=1{\cdot}61187\ ;\ v_1={\cdot}77314,\ v_2={\cdot}81103.$$

Therefore

$$\beta=\frac{0{\cdot}497709-0{\cdot}496245}{0{\cdot}03188}=\frac{0{\cdot}001464}{0{\cdot}03188}=0{\cdot}0459.$$

Here the difference between the two terms of the numerator is only $\frac{1}{350}$ of either, and as each term involves only the fractional part of the index, any error in μ is multiplied about 900 times in its effect on β.

This makes it imperative to attach weight only to those experiments where special appliances have been adopted to keep the temperature constant during the observations. For this reason I simply allude to the few results I have myself obtained in a few preliminary experiments, reserving data for a fuller discussion. The results here presented depend almost entirely on the work of three sets of observers, namely, Nasini and Bernheimer, Perkin, and Ketteler. It would be invidious for me to single out one of these as more accurate than the others ; their papers show that all the experiments are of a high order of accuracy. It is doubtful, however, whether Perkin's data are not the most serviceable for our present purpose, if only for the reason that the interval of temperature he employed is greater, with the consequence that the differences on which β depends become more marked, and thereby afford greater accuracy.

Table I. is drawn up from a paper by Nasini and Bernheimer*. They were the first to use a jacketed prism, so that their results are the earliest of those suitable for deducing β. One substance in their list—bromonaphthalene—has been omitted, as it stands alone in giving an increase in $(\mu-1)v$ on heating. It is probable that the limit of experimental error is reached with that substance.

TABLE I.

Substance.	Temp.	Density.	μ_α.	$\beta = \frac{(\mu-1)v-(\mu_1-1)v_1}{\mu-\mu_1}$.	v at lower temp.	$\frac{\beta}{v}$.
Thymol, $C_{10}H_{14}O$.	24°	0·96895	α1·51453	0·0563		
	77·3	0·92838	α1·49189	0·0600		
				0·0623		
				Mean 0·0600	1·0320	0·058
Cinnamic Alcohol, $C_9H_{10}O$.	24·8	1·04017	1·57311	0·077		
	77·3	1·00027	1·54939	0·086		
				0·011		
				0·080	0·96055	0·083
Anethol, $C_{10}H_{12}O$.	14·9	0·99132	1·55559	0·066		
	77	0·94041	1·52526	0·063		
				0·069		
				0·066	1·0087	0·0655
α-Methyl α-Naphthol, $C_{11}H_{10}O$.	14	1·09636	1·61474	0·0566		
	77	1·04661	1·58508	0·0570		
				0·0850		
				0·0620	0·9121	0·0680
Dimethylnaphthalene, $C_{12}H_{12}$.	16·4	1·01803	1·60765	0 0869		
	77	0·97411	1·57901	0·0899		
				0·0893		
				0·0890	0·9823	0·09

Column 2 gives the temperatures, 3 the densities, and 4 the indices for the line α. Col. 5 gives three values of β as calculated from the two indices for each of the lines α, D, and β. The indices for D and β will be found in the original paper.

* *Gaz. Chim. Ital.* XV., 1885.

The third value (that given by Hβ) for cinnamic alcohol appears to be wrong, and the third value for methyl α-naphthol also, though to a less degree. In calculating the means, I have ignored the first and allowed only half weight to the second of these.

The next table contains all the observations made by Perkin*, whose apparatus was still more perfect than that of Nasini and Bernheimer. The index is quoted here for the line D only, but the quantity β has been calculated from the lines A, C, D, and F. Where a fifth value is given, it is calculated from the line G.

Tables I. and II. contain the results yielded by substances of very varied chemical types. It may be stated at once that, although the last six substances have been put in the Table, the discussion of the figures they yield will be deferred. It is known that they are of very exceptional character; for example, that they change in chemical constitution when heated, so that it is not strictly the same substance we are dealing with at the two temperatures given in the Table†. Excluding these compounds, the values of β are of a satisfactory order. They do not vary largely, the extreme values being 0·09 and 0·043, most of them lying between 0·065 and 0·045. That is to say, on the hypothesis which led to the calculation, the actual space filled by one gramme of the substance is about one twentieth of a cubic centimetre.

Column 7 shows the value of β/v, that is the ratio of the actual to the apparent volume of a liquid. The extremes are 0·15 and 0·054. If we exclude methylene di-iodide, a substance of exceptional density, the extremes are 0·09 and 0·054, and twelve out of the sixteen liquids lie between 0·076 and 0·054; the average value is 0·064.

These results are promising, both with regard to the absolute magnitude and the approach to similarity of value for the different liquids. This last fact was to be expected, for it is probable that ordinary liquids, under similar conditions of temperature and pressure, have volume constitutions of a fairly uniform type.

* Chem. Soc. Journ. 1892, pp. 287 & 800.

† Compare Perkin, Chem. Soc. Journ. 1892, p. 840.

TABLE II.

Substance.	Temp	Density.	μ_D.	$\beta = \frac{(\mu-1)v-(\mu_1-1)v_1}{\mu-\mu_1}$	v at lower temp.	$\frac{\beta}{v}$.
Heptane, C_7H_{16}	12·2°	0·69026	1·39220	0·0808		
	88·8	0·62301	1·35197	0·0810		
				0·0813		
				0·0814		
				Mean 0·0810	1·4487	0·056
Octyl Iodide, $C_8H_{17}I$.	14	1·34096	1·4922	0·0467		
	88	1·25332	1·4579	0·0476		
				0·048		
				0·0475	0·7457	0·063
Methylene Iodide, CH_2I_2.	8	3·3480	1·74935	0·0425		
	87	3·1390	1·69500	0·0429		
				0·0442		
				0·0445		
				0·0440	0·29868	0·15
Toluene, C_7H_8	10·7	0·87532	1·5028	0·0677		
	90	0·79949	1·45673	0·0683		
				0·0688		
				0·0709		
				0·0688	1·1424	0·06
Phenyl Chloride, C_6H_5Cl.	9·6	1·1167	1·53103	0·0421		
	89·2	1·0302	1·48731	0·0533		
				0·0572		
				0·0543		
				0·0577		
				0·0540	0·8955	0·06
Phenyl Bromide, C_6H_5Br.	4·2	1·5100	1·56845	0·0458		
	89·2	1·39638	1·52235	0·0440		
				0·0464		
				0·0487		
				0·052		
				0·047	0·66225	0·071
Phenyl Iodide, C_6H_5I.	8	1·8482	1·62755	0·0444		
	88	1·7272	1·58301	0·0441		
				0·0450		
				0·0461		
				0·0465		
				0·0452	0·54107	0·083
Aniline, C_6H_7N	11·2	1·02792	1·5912	0·0490		
	90·1	0·95783	1·54867	0·0513		
				0·0546		
				0·0537		
				0·0538		
				0·0525	0·97283	0·054

Table II. (*continued*).

Substance.	Temp.	Density.	μ_D.	$\beta = \frac{(\mu-1)v-(\mu_1-1)v_1}{\mu-\mu_1}$	v at lower temp.	$\frac{\beta}{v}$.
Dimethylaniline, $C_8H_{11}N$.	° 8	0·96688	1·56535	0·0610		
	89·7	0·89961	1·52345	0·0665		
				0·0671		
				0·0850		
				0·068	1·03425	0·065
a-Naphthylamine, $C_{10}H_9N$.	51	1·10043	1·67084	0·060		
	88·4	1·07207	1·65209	0·0678		
				0·0704		
				0·0800		
				0·069	0·90873	0·076
Ethyl Cinnamate	12·9	1·05560	1·56351	0·060		
	91·1	0·98815	1·52500	0·0663		
				0·0684		
				0·080		
				0·068	0·94733	0·071
Acetyl-acetone	11	0·98506	1·44493	0·211		
	99·3	0·89787	1·39634	0·222		
				0·224		
				0·251		
				0·278		
				0·240	1·0152	0·235
Methyl-acetyl-acetone.	8·34	0·99189	1·44210	0·173		
	99·2	0·90324	1·39526	0·178		
				0·185		
				0·207		
				0·186	1·0081	0·185
Ethyl-acetone-oxalate.	17	1·12879	1·46503	0·0676		
	100	1·04109	1·42617	0·0700		
				0·0772		
				0·0760		
				0·0710	0·8859	0·080
Ethyl-diaceto-acetate.	17·6	1·09313	1·45729	0·0476		
	99·8	1·0675	1·41932	0·0479		
				0 0487		
				0·0530		
				0·0603		
				0·0515	0·9148	0·0564

Table II. *(continued)*.

Substance.	Temp.	Density.	μ_D.	$\beta = \frac{(u-1)v-(\mu_1-1)v_1}{\mu-\mu_1}$.	v at lower temp.	$\frac{\beta}{v}$.
Diacetyl-acetone	60°	1·04248	1·46691	0·292		
	99·8	1·00615	1·44386	0·291		
				0·309		
				0·350		
				0·314	0·96146	0·326
Allyl-acetyl-acetone ...	13·5	0·97671	1·46156	0·1515		
	99·2	0·89832	1·41868	0·1614		
				0·1680		
				0·1894		
				0·205		
				0·175	1·0238	0·1709

It may be objected that the average values obtained for β and β/v are much too small, seeing that other estimates of these quantities give much larger figures. The ratio

$$\frac{\text{actual volume of molecules}}{\text{apparent volume of liquid}}$$

is generally estimated to be about 0·2 or 0·3; that is, about four times greater than the value now found by the new hypothesis.

To this objection it may be replied :—

1. Prof. Tait has expressed the opinion that "the estimates hitherto made can hardly be called even rough approximations. But probably the particle does not occupy so much as 5 per cent. of its share of the whole content"*. This estimate is not far from the 6 per cent. yielded by the foregoing calculations.

2. It will be suggested at a later stage that the expressions which give 0·2 or 0·3 for the ratio β/v probably measure, not the molecular volume itself, but that part of the apparent volume which may be called the molecular domain.

Postponing further consideration of this argument, we may inquire whether the value of β is dependent on the particular

* Tait, 'Properties of Matter,' p. 90.

temperatures employed in the observations. That is to say, presuming that it is a measure of molecular volume, does it show any change in value at higher or lower temperatures? Very few series of observations are accurate enough to stand the severe test imposed on them by an attempt to answer this question. Of the few that seem suitable, I shall give two examples, taken from the work of Ketteler*. From these it will appear that the answer varies, carbon disulphide showing a constant value for β at different temperatures, while water gives a *diminishing* value as the temperature rises.

Carbon Disulphide, CS_2.

Temperature.	v.	μ_D.	β.	$(\mu-1)(v-\beta)$.
-20°	0·75582	1·65950	0·0476	0·46879
−10	0·76442	1·65158	0·0476	0·46878
0	0·77314	1·64375	.....	0·46874
10	0·78207	1·63593	0·046	0·46872
20	0·79131	1·62806	0·046	0·46873
30	0·80093	1·62004	0·0464	0·46871
40	0·85515	1·61187	0·0459	0·46871

Here it is evident that the value of β remains practically constant through a range of 60° C. The values given were calculated from 0° as one of the temperatures in each case.

If β has the meaning here assigned to it, the above measurements indicate that 1 gram of carbon disulphide actually occupies 0·046 cubic centimetre. Moreover, if we take the ratio β/v, we find it to be 0·062 at 0° C., which is again very near the average value yielded by the many liquids already given.

* *Ann. Phys. Chem.* xxxv. p. 693.

Water.

Temperature,	v.	μ_D.	β calculated from first.	β calculated for each pair.
20·9	1·00196	1·33287	.....	
31·0	1·0044	1·33177	0·204	·204
56·0	1·0149	1·32776	0·150	·114
87·0	1·0336	1·32107	0·114	·085
94·0	1·0386	1·31943	0·108	·067

The result here is quite different from that shown by carbon disulphide ; β varies with every change in the temperature. It is given in two columns, the first containing values obtained by taking each observation in conjunction with that at the lowest temperature. The next column contains values obtained by taking each pair of observations. This last series is the more suggestive.

1st. It shows β to be *diminishing* as the temperature rises, and gives the value it has between 87° and 94°. At this temperature, where the water is approaching its boiling-point, the value of β becomes 0·067 cubic centim., a close approximation to that given by the other liquids.

2nd. The ratio β/v at the high temperatures is 0·063, almost exactly the ratio 0·064 given by the other liquids.

These results are suggestive, and at once raise a question as to the meaning of the diminution in β as the temperature rises towards boiling-point. Any one acquainted with recent researches on the physical properties of liquids will at once recall those of Ramsay and Shields on Molecular Complexity; those of Thorpe and Rodger on Viscosity of Liquids, &c., as bearing on this question. The investigations mentioned, along with others, have rendered it almost certain that the molecule of water is a complex of the form $n\mathrm{H_2O}$, and that the value of n in this expression diminishes as the temperature rises. Consequently the high value now found for the volume of the water molecule, as measured by β, appears to be another indication of its greater molecular complexity, and

the fall towards normal value as boiling-point is approached points to a molecular simplification as indicated by the other methods.

Somewhat similar, though more erratic, is the available evidence with regard to other liquids of known molecular complexity, such as the alcohols and acetic acid. The figures are not now quoted, as they must be redetermined with greater accuracy and perfect exclusion of atmospheric moisture during the experiments.

We may now test the value of β in another way. It has already been mentioned that the ordinary Gladstone expression fails to deal with the transition from liquid to gas, and the suggestion is now made that the discrepancy is due to the neglect of the volume of the particles, a quantity which practically vanishes in the case of vapours.

The question arises, will the value of β deduced from a liquid bring the liquid and gaseous numbers into agreement? Not many observations are available for this comparison. Obviously the same specimen ought to serve for the liquid and vapour. The work of Lorenz* and Prytz almost exhausts the published data of this sort.

Lorenz gives two observations on the liquid at different temperatures, and also an observation on the vapour formed by the liquid. Unfortunately Lorenz selected the temperatures of 10° and 20° C. for the observations on the liquids, which are too near one another to afford a very satisfactory basis for calculating β. Notwithstanding this, the results as shown in the following table (p. 683) are very encouraging.

This table shows that the difference between the specific refraction of a liquid and its vapour as calculated by the Gladstone expression may be 10 per cent. of the whole; also that if the value of β as calculated from the liquid be employed in the modification now proposed, the difference between the liquid and vapour falls to less than 1 per cent. With a more accurate estimate of β this difference might be still further reduced. The modified expression gives practically a constant for both liquid and vapour.

One remark ought to be made. The value of β for carbon

* Wied. *Ann.* 1880.

Substance.	Temp.	Specific Refraction $(\mu-1)v$.		β calculated from Liquid.	Specific Refraction $(\mu-1)(v-\beta)$.	
		Liquid.	Vapour.		Liquid.	Vapour.
Carbon Disulphide ...	10°	·4889	·4289	0 0886	·4334	·4289
" " ...	20	·4882				
Chloroform	10	·2979	·2681	0·0672	·2677	·2681
"	20	·2975				
Ethyl Iodide.....	10	·2634	·2334	0·0685	·2282	·2334
" "	20	·2629				
Ethyl Acetate	10	·4148	·401	0 030	·4035	·401
" "	20	·4147				
Ethyl Ether	10	·4905	·4561	0·098	·4554	·4561
" "	20	·4900				

disulphide is much greater than that deduced from Ketteler's figures already quoted; a fact which is difficult to explain, though difference of specimen may have something to do with it.

There is another set of observations by which β can be tested. Prytz has given data for nine liquids and their vapours; but as he only took one observation on the liquid his work is only available for calculating β from the liquid and vapour values. This can be compared with the average values previously obtained.

Substance.	β calculated from Liquid and Gas.
Methyl Alcohol	0·09
Ethylene Chloride	0·116
Ethedene "	0·085
Acetone	0·091
Methyl Acetate	0·0655
Ethyl Formate	0·093
Propyl Iodide	0·112
Methyl Propionate	0·096
Benzene.....	0·16

These values are slightly higher than those deduced from two observations on the liquid, but the difference is not great.

A *prima facie* case having been shown for attaching some physical significance to the symbol β, it appeared probable that the values for different substances would show definite

relationships between themselves; or that the value of β for a given substance would be related to the value of v at the freezing, boiling, or critical temperature.

Of these the boiling-point is the one for which data are mostly available, and a little examination suggested a close relation between the absolute temperature of the boiling-point and the two volumes v and β. It may conveniently be written

$$\beta \propto \frac{v_T}{\sqrt{T}}.$$

For the Centigrade scale the relation indicated seems to approach one of equality.

There are ten substances for which β, v_T, and T are known with sufficient (or apparently sufficient) accuracy. The above equation is here used to find the value of β from v and T, and the value so obtained is compared with that given by the optical data.

The following table shows that the results are in fair agreement, if we remember that the three data compared together are mostly due to different observers using different specimens.

Substance.	v_T.	$\sqrt{T}$.	$v_T \div \sqrt{T}$	β from refraction.
Heptane	1·629	19·3	0·084	0·081
Carbon Disulphide ...	0·818	17·89	0·0457	0·0460
Aniline	1·146	21·2	0·054	0·0525
Toluene.....	1·282	19·62	0·065	0·068
Water	1·043	19·34	0·054	{ 0·067 ? 0·060 ?
Phenyl Chloride	1·044	20·1	0·052	0·054
Phenyl Bromide	0·766	20·7	0·0365	0·047
Phenyl Iodide	0·6388	21·5	0·03	0·045
Ethyl Cinnamate.....	1·2005	23·15	0·052	0·068
Ethylene Dibromide...	0·5178	20·13	0·026	0·031

Many other figures might be given but they are of inferior accuracy, and ought not to be placed along with those just quoted. The examples are sufficient to establish a case for further inquiry, inasmuch as the agreement is close enough in six or seven cases to preclude the notion of accidental coincidence.

If additional data confirm the foregoing result, it affords

us another method of calculating the quantity β when the boiling-point and the density at that temperature are known. I propose to get β for other substances by this method, and test several deductions by the result. It is evident, on general grounds, that values of β calculated by this method will be of the same order of magnitude as that given by the optical data. All ordinary liquids boil between, say, 50° and 300° Centigrade, or 320° and 470° absolute; and the square roots range between 18 and 22, with average about 19, which is fairly near the average ratio for v_1/β.

It is hardly necessary to point out that this relation may possibly supply a hint as to the unknown law between volume-relationships of liquids and the temperatures. For example, I was tempted to compare the varying value of β in the case of water with its very varied coefficient of thermal expansion α.

Apparently, these two quantities are inversely proportional, as shown in the following table by the comparative constancy of the product $\beta \times \alpha$.

Water.

Temperature-range.	β.	α.	$\beta \times \alpha$.
20°·9 to 31°	0·203	·00025	·0000505
31 „ 56	0·144	·0004	·0000576
56 „ 87	0·082	·00059	·0000482
87 „ 94	0·067	·00072	·0000482

In reading this table the approximate character of the value for β must be kept in mind. The last column then indicates the probability of some connexion between β and α. α is calculated from data given by Thorpe.

Slight though this evidence may appear it seems to me to warrant further careful investigation, in view of the desirability of finding some method of obtaining a general law governing the thermal expansion of liquids, and the admitted difficulty of the problem.

Note.—I have quite recently calculated the value of β from another series of figures due to Ketteler, and quoted in Landolt and Bornstein's tables. The general tendency is as above, but the product $\beta \times \alpha$ varies from $\cdot 0_4 428$ to $\cdot 0_4 600$. There is perhaps internal evidence, however, for regarding the figures as less accurate than the foregoing, so that I let the matter stand, subject to correction.

Summing up the general results obtained so far, we find:—

1. In simple liquids the quantity β lies between narrow limits, the average being 0·05 cubic centim.
2. The ratio β/v averages 0·064. That is, the actual volume of the molecules is about 6 per cent. of the apparent volume.
3. Liquids known to have exceptional physical properties, such as water &c., give higher values of β than usual. This higher value changes with temperature, and is probably a measure of molecular complexity.
4. There is reason to think that some liquids, like carbon disulphide, yield a constant value for β at different temperatures.
5. The value of β given by a liquid enables us to apply the Gladstone formula (amended) during the transition from the liquid to the gaseous state.
6. There are grounds for believing that the value of β is related to other volume-relationships of the substance, as, for example, the specific volume at the boiling-point.
7. In some cases there may be a connexion between β and the coefficient of thermal expansion.

A further argument for the introduction of the quantity β is the fact that it will remove certain anomalies in molecular refractions, bringing the value for hydrogen, chlorine, &c. into harmony with that given by the gaseous elements. This point, together with others of a like nature, is reserved for another paper.

So far as the suggestions thrown out are probable, it would appear that "the actual volume of the particles" is not a correct expression for β. In the case of water, β has a varying value, which is attributed to the resolution of its

complex molecule into simpler forms. But such resolution could not diminish the volume of the particles, unless we mean by this phrase "the true volume of the atoms + the inter-atomic space." If we imagine a surface drawn to enclose the molecule, it will include such space as lies between the atoms in that molecule. Similarly, when two molecules coalesce to form one of greater complexity the space occupied by the two is greater than before. They do not actually touch, so that the enclosing surface has a greater volume than twice that which encloses one molecule.

The results obtained so far show that the modified Gladstone expression promises to cover all ranges of density*. This wide range of applicability is obtained by emphasizing the volume-relationships involved in the formula—a fact which acquires further significance when we remember that it is as a measure of a volume that the Gladstone expression has proved so useful. For the specific refraction of a substance, $(\mu-1)v$, is evidently a fractional part of the specific volume v. Moreover, both Dufet (*Journ. de Phys.* 1885) and Sutherland (Phil. Mag. 1888), in developing a theoretical basis for the Gladstone law, have shown that "volume of molecules" is involved, though the exact definition of the phrase is not arrived at.

It seemed worth while asking whether this fractional part of the volume had a physical meaning. If the quantity β may be regarded as a measure of true molecular volume, and there still remain a certain element of volume to be measured, it will most probably be found by accepting a well-known kinetic constitution for the liquids. If temperature be constant, we may assume that each molecule of a liquid vibrates as a whole over a certain region called its domain, the centre of this region being defined as the centre of the molecule when in its mean position.

The extent of the domain, and the relation between it and the total volume, will depend on the energy of molecular motion, and on the law of molecular force with regard to distance.

* Except perhaps in the case of certain solids. See data for refraction of solids collected in the paper by Dr. Gladstone and myself already mentioned, Chem. Soc. Trans. 1895, p. 831.

Thus the apparent volume is made up of fractional parts, one of which may be called the sum of the volumes of the molecules, another the sum of the volumes of the domains, and a third the interstitial spaces. A satisfactory theory for evaluating these can perhaps not be found till more is known of the magnitude and law of the molecular forces, but an empirical examination suggested that $(\mu-1)v$ might possibly serve as a basis for finding the domain. At any rate it gives by transposition a part of v which fairly answers to the only criterion of the domain which I can lay down.

Nothing is known as to possible change of the dimensions of the molecules themselves, but it seems highly probable that the domain of a given substance will most certainly differ under different physical conditions. Still further does it seem probable that the domain of different substances, heated between the same temperature-limits, may change in the same ratio. Figures in the tables which follow will prove this for the new expression, to what may be called a first approximation.

The transformation referred to is

$$(\mu-1)v=\mu\left[v-\frac{v}{\mu}\right],$$

the value of the square bracket on the right being equal to $\frac{\mu-1}{\mu}.v$.

It was evident to me, and will be to any one familiar with the data given by molecular refractions, that this last expression gives a fraction of v tolerably near that obtained by the use of the other well-known expression

$$\frac{\mu^2-1}{\mu^2+2}.v.$$

I can best illustrate this by taking a table from a lecture on the "Range of Molecular Forces" delivered to the Chemical Society by Rücker (Chem. Soc. Journ. 1888, p. 253).

Using Hopkinson's data, Rücker compares the values of

$$\frac{K-1}{K+2} \quad \text{and} \quad \frac{\mu^2-1}{\mu^2+2}$$

for five substances (K = specific inductive capacity). His object is to show that the figures justify well-known theories due to Clausius, Clerk-Maxwell, and others. Assumptions underlying these expressions make them a measure of the ratio

$$\frac{\text{true volume of molecules}}{\text{apparent volume of liquid}},$$

though the expression "true volume of molecules" is a quantity depending on what is better known as the "diameter of the molecule," *i. e.* the smallest distance between the centres of molecules.

The table is quoted bodily, with an additional column to show the value of $\frac{\mu-1}{\mu}$, this last being the factor of v in the square bracket of the transposed expression.

Substance.	Formula.	K.	μ^2.	$\frac{K-1}{K+2}$.	$\frac{\mu^2-1}{\mu^2+2}$.	$\frac{\mu-1}{\mu}$.
Amylene	C_5H_{10}.	2·05	1·9044	0·260	0·232	0·245
Benzol	C_6H_6.	2·38	2·2614	0·315	0·296	0·334
Toluol	C_7H_8.	2·42	2·2470	0·321	0·291	0·333
Xylol.....	C_8H_{10}.	2·39	2·2238	0·317	0·290	0·329
Cymol	$C_{10}H_{12}$.	2·25	2·2254	0·294	0·290	0·295

Here it is evident that there is a close agreement among the three sets of figures, amply sufficient to justify further examination. So far as differences occur, $\frac{\mu-1}{\mu}$ is nearer $\frac{K-1}{K+2}$ than is $\frac{\mu^2-1}{\mu^2+2}$.

In pursuing this comparison I shall introduce β, so that

$$(\mu-1)(v-\beta)=\mu\left[(v-\beta)-\frac{v-\beta}{\mu}\right].$$

The square bracket is equal to

$$\frac{\mu-1}{\mu}(v-\beta),$$

and it is under this head that the figures appear in the following tables :—

Carbon Disulphide.

Temperature.	$\frac{\mu^2-1}{\mu^2+2}.v.$	$\frac{\mu-1}{\mu}.(v-\beta).$	$\frac{v-\beta}{\mu}.$	$\frac{v-\beta}{\mu}$ calculated.
-20°	0·2788	0·2821	0·4277	0·4259
−10	0·2793	0·2835	0·4349	0·4341
0	0·2798	0·2847	0·4424	0
10	0·2803	0·2867	0·4494	0·4502
20	0·2808	0·2875	0·4578	0·4581
30	0·2813	0·2890	0·4659	0·4659
40	0·2819	0·2904	0·4746	0·4735

The experimental data are Ketteler's, and have already been given.

On comparing columns 2 and 3, it is seen that the figures are remarkably close to one another. The difference is just over 1 per cent. at −20°, and though it increases as the temperature rises, it only just exceeds 3 per cent. at +40° C.

Column 4 contains the values of the second term in the bracket, or $\frac{1}{\mu}$th of $v-\beta$; and column 5 contains the "calculated" values for the same expression. The calculation is made by taking the value at 0° C. and multiplying by the square root of the ratio of absolute temperatures. Thus the value at −20° is equal to

$$0{\cdot}4424\times\sqrt{\frac{254}{274}}=0{\cdot}4259.$$

I was led to try this by the results obtained in the first part of the present paper, and the extremely close approximation of the calculated to the other numbers is surely of some importance. The quantity $\frac{v-\beta}{\mu}$ will be referred to as the interstitial space.

The next table contains data for substances already mentioned.

Substance.	Temp.	$\frac{\mu-1}{\mu}(v-\beta)$.	$\frac{\mu^2-1}{\mu^2+2}v$.	Difference.		Ratio of New Values.
				Actual.	per cent.	
Thymol	24°4	0·39022	0·3110	0·079	20	1·0154
	77	0·39542	0·3124	...	...	
Cinnamic Alcohol	24·8	0·3208	0·3168	0·004	1·2	1·0152
	77	0·3261	0·3182	...	...	
Anethol	14·9	0·3378	0·3241	0·0137	4	1·0199
,,	77	0·3445	0·3260	...	...	
α-Methyl α-Naphthol	14	0·3255	0·3182	0·007	2	1·0187
,, ,,	77	0·3316	0·3202	...	...	
Dimethyl Naphthalene	16	0·3377	0·3395	−0·0018	−0·6	
	78	0·3438	0·3412			
Heptane	12	0·3853	0·3451	0·04	10	1·030
,,	89	0·3968	0·3471	...	...	
Octyl Iodide	14	0·2303	0·2164	0·014	6	1·024
,,	88	0·2358	0·2177	...	−11	
Methylene Iodide	8	0·1091	0·1216	−0·012	...	1·0318
,,	87	0·1126	0·1225	...	...	
Toluene	10·7	0·3591	0·3376	0·021	6	1·0312
,,	90·3	0·3703	0·3403	...	...	
Phenyl Chloride	9·6	0·2922	0·2771	0·015	5	1·029
,,	89	0·3007	0·2793	...	...	
Phenyl Bromide	4·2	0·2230	0·2168	0·006	3	1·031
,,	89·2	0·2296	0·2185	...	...	
Phenyl Iodide	8	0·1913	0·1919	−0·0006	−0·3	1·028
,,	88	0·1967	0·1935	...	...	
Aniline	11·2	0·3417	0·3288	0·013	4	1·0273
,,	90·1	0·3511	0·3319	...	...	
Dimethylaniline	8	0·3462	0·3336	0·0126	3·6	1·0304
,,	89·7	0·3567	0·3363	...	...	
Ethyl Cinnamate	12·9	0·3169	0·4210	0·104	33	1·0255
,,	91·1	0·3250	0·4378	...	...	
α-Naphthylamine	51	0·3370	0·3396	−0·0026	0·8	
,,	88·4	0·3408	0·3409	...	...	
Acetyl-acetone	11	0·2387	0·2702	0 0315	13	1·0349
,,	99·3	0·2488	0·2678	...	...	
Methyl-acetyl-acetone	8·34	0·2560	0·2668	−0·0108	4	1·033
,,	99·2	0·2800	0·2656	...	...	
Ethyl-acetyl-acetone	15·4					
,,	100·3					
Ethyl-acetone-oxalate	17·0	0·2587	0·2449	0·0138	5	1·0272
,,	100·0	0·2665	0·2545	...	...	
Ethyl-diacetol-acetate	17·6	0·2710	0·2493	0·0217	8	1·0267
,,	99·8	0·2615	0·2367	...	...	
Diacetyl-acetone	60·0	0·2065	0·2667	−0·0602	29	
,,	99·8	0·2089	0·2639	...	...	
Allyl-acetyl-acetone	13·5	0·2681	0·2812	−0·0131	5	1·0322
	99·2	0·2769	0·2809	...	...	
Ethyl Acetate	10	0·2909	0·2546	0·0363	12	1·0039
,,	20	0·2920	0·2549	...	...	
Chloroform	10	0·1848	0·1990	0·0058	3	1·0040
,,	20	0·1855	0·1791	...	...	
Ethyl Alcohol	10	0·3266	0·2804	0·046	14	1·0029
,,	20	0·3276	0·2807	...	...	
Ethyl Iodide	10	0·1514	0·1557	−0·0043	3	1·0046
,,	20	0·1521	0·1558	...	...	
Carbon Disulphide	10	0·2668	0·2805	−0·013	5	1·0049
,,	20	0·2681	0·2809	...	...	

On examining this table we find that the new expression gives results which very fairly agree with those derived from Lorentz's formula. The average difference between the two is about 5 per cent., a difference not greater than that which would be yielded by the expressions of Clausius and Maxwell. So far as this agreement goes we may regard

$$\frac{\mu-1}{\mu}(v-\beta)$$

as a fair approximation to a volume quantity, which I may be allowed to call "molecular domain."

The value, as given by either formula, increases with the temperature. The highest increase by the μ^2 expression is about one per cent. in the case of aniline. Whether such an increase could be attributed to the molecule proper, is an unsolved problem. It is usual to regard the values yielded by the Lorentz formula as more constant than here appears, but the figures are too numerous and too reliable to leave any doubt about the magnitude of the change.

As I have already said, it seems probable that domains will change in the same ratio between the same temperature limits. This can be tested for the new expression by the figures in the last column, which gives the ratio of the two values for

$$(v-\beta)-\frac{v-\beta}{\mu} \text{ or } \frac{\mu-1}{\mu}(v-\beta)$$

found at two temperatures.

To facilitate comparison, the substances are arranged in groups, marked off by a line. The members of each group are heated between approximately the same temperatures. Thus thymol is heated between 24°·4 and 77°, cinnamic alcohol between 24°·8 and 77°. The domain of the first increases in the ratio 1·0154, that of the second in the ratio 1·0152.

The members of the large group beginning with heptane and ending with ethyl cinnamate are heated between limits the lower of which lies between 4° and 12°, while the upper limit lies between 87° and 90°. The new domain rises generally in this group by 3 per cent. Out of the ten substances, seven give a ratio of increase very near to 1·030, the other three are near 1·027.

The next group includes eight substances heated between, say, 12° and 100°. Three give ratios close to 1·033, two yield 1·027. The last group is heated from 10° to 20° only, and gives ratios close to 1·004, except in the case of alcohol.

These results seem to afford a reasonable presumption in favour of the figures being regarded as a measure of domain. There is evidently a tendency for the ratio of increase to be the same for the different liquids, although their densities vary in the ratio of 5 to 1. It is surely improbable that molecules of very varying atomic structure should have the same temperature increase, but the same improbability does not attach to "domain."

There is, however, one aspect of this question which may prove to be still more important. It may be objected that the empirical* expression here used for obtaining the domain is too fanciful to be regarded with serious consideration. It may further be pointed out that it is equivalent to

$$(\mu-1)(v-\beta)\times\frac{1}{\mu},$$

as we have seen, and that the first two factors give a constant. Any relationships like those just alluded to must therefore be dependent on a more or less common temperature function for the refractive index.

* In the June number of the Chem. Soc. Journal appears an abstract of a paper by W. F. Edwards (American Chem. Journ.), who obtains the expression now proposed, as a new formula for specific refraction, thus:— If V and V_1 are the velocities of light in space and the substance respectively, $\mu=\frac{V}{V_1}$. Let $A=V-V_1$, then $A=\frac{\mu-1}{\mu}V$. If the difference A is proportional to the amount of substance, and assuming as unit one gramme of substance in 1 cub. centim., and that X is the retardation of velocity for unit substance, then

$$X=\frac{\mu-1}{\mu}V\times\frac{1}{d}.$$

This is the same expression as that I propose for domain, multiplied by V. As will be seen from my tables, and as Edwards shows, the value of X is not a constant. It cannot therefore serve as a measure for specific refraction unless under stated conditions of temperature. He promises to return to this, but will, I believe, only find the solution by substituting "volume of domain" for volume of substance. As will be seen, I obtain his expression by a transformation of the Gladstone expression.

It is evident, apart from arithmetic error, that this must be so. But such an objection, while having weight against an expression obtained by the method we have pursued, at once raises a very suggestive question. Does the evidence really justify the idea that the refractive indices of various substances change in the same ratio between the same temperature limits? In other words, Is the ratio magnitude of the change independent of the nature of the liquid? The following table gives the evidence available. The substances quoted are those already dealt with, but the comparison deals directly with the refractive indices, and is therefore free from all objections which might be urged against the hypothesis of this paper.

To facilitate comparison, the substances are again divided into groups, the order being slightly different from that previously given. The refractive indices are given in column 3; column 4 gives the ratio of the two indices, which are slightly corrected in column 5. This is done by calculating from columns 2 and 3 the average change in the index per degree, as shown in column 6. The figure thus obtained is used to calculate the change of index for 80° exactly, which means an alteration of only a degree or two for most substances. The ratio in column 5 is calculated then for a common interval of 80°, and will be somewhat nearer the truth than the uncorrected ratio in column 4.

Column 7 gives the exponent of μ in the statement $\mu^x \propto \frac{1}{T}$, where T is the absolute temperature. It therefore equals

$$\log \frac{T_2}{T_1} \div \log \frac{\mu_1}{\mu_2}.$$

The ratio $\frac{\mu_1}{\mu_2}$ is about 1·03, so that the different powers of it do not vary so much.

An examination of this table will show that for the same temperature limits there is a fair approach to constancy in the ratio $\frac{\mu_1}{\mu_2}$.

Thus the indices of the first seven substances all give

Substance.	Temp.	μ.	$\frac{\mu_1}{\mu_2}$.	$\mu_1 \div \mu_2$ corrected.	$\frac{\mu_1 - u_2}{T_2 - T_1}$.	$x = \frac{\log \frac{T_2}{T_1}}{\log \frac{\mu_1}{\mu_2}}$.
Heptane	12°	1·3922	1·0297	1·0317	·000522	8·1
„	89	1·35197				
Methylene Iodide	8	1·74935	1·0321	1·0325	·000671	8·0
„	87	1·69500				
Toluene	10·7	1·5028	1·0316	1·0318	·000576	8·05
„	90	1·45673				
Phenyl Chloride	9·6	1·53103	1·0293	1·0295	·000546	8·84
„	89·2	1·48731				
Acetyl-acetone	11	1·44493	1·0349	1·0314	·000552	7·92
„	99·3	1·39634				
Methyl-acetyl-acetone	8·34	1·4421	1·0334	1·0295	·000514	8·49
„	99·2	1·39526				
Ethyl-acetyl-acetone	15·4	1·44066	1·0324	1·0307	·000535	8·0
„	100·3	1·3952				
Phenyl Bromide	4·2	1·56845	1·0303	1·0285	·000543	9·46
„	89·2	1·52235				
Phenyl Iodide	8	1·62755	1·0279	1·0279	·000557	9·17
„	88	1·58301				
Aniline	11·2	1·5912	1·0274	1·0278	·000538	9·23
„	90·1	1·5487				
Dimethylaniline	8	1·5583	1·0270	1·0265	·000510	9·6
„	89·7	1·51704				
Ethyl-acetone-oxalate	17	1·46503	1·0272	1·0262	·000536	9·35
„	100	1·4263				
Ethyl-diaceto-acetate	17·6	1·4573	1·0270	1·0261	·000463	9·29
„	99·8	1·4193				
Ethyl Cinnamate	12·9	1·5479	1·0253	1·0259	·000476	9·93
„	91·1	1·5108				
Octyl Iodide	14·5	1·4922	1·0236	1·0254	·000463	9·99
„	88·5	1·4579				
Thymol	24	1·5145	1·0154	1·0154	·000427	10·7
„	77·3	1·4919				
Cinnamic Alcohol	24·8	1·5731	1·0153	1·0153	·000447	10·6
„	77·3	1·5494				

ratios very near to 1·031. This is specially striking if we take particular cases like the first two on the list—heptane and methylene di-iodide—as shown in the following short table (p. 696).

It is also noteworthy that this same ratio (1·03) holds good in the case of those substances whose tendency to tautomerism is productive of anomalies. These are acetyl-acetone, methyl-acetyl-acetone, and ethyl-acetyl-acetone, which give abnormal values for β, and which differ from all other substances, even when tested by the Lorentz formula. Of course the ratio 1·03 is not preserved all the way down this group; the lower

	Temp.	Density.	Between the same temp. limit.	
			Ratio of Densities.	Ratio of Indices.
Heptane	12°	0·6903	1·11	1·0317
„	89	0·6230		
Methyl Di-iodide.....	8	3·348	1·07	1·0325
„ „	87	3·139		

members fall to about 1·026. Whether this means only a slight departure from the other value, or whether it indicates a breakdown of the suggested constant relationship can only be decided when many more accurate temperature observations are obtainable. The ratio altogether breaks down in the case of such substances as water, which, as I have suggested, show special relations to refractive index by reason of varying molecular complexity.

The last column in the foregoing table gives the ratio of the logarithms of temperatures and indices. Further research may make this column more valuable than it now appears.

Taken altogether, the table affords ground for believing that there are close relationships between refractive index and temperature, and, further, that the ratio of change for a particular temperature interval may be the same for many different liquids.

The question then arises, whether this last relation is direct, or arises from some material property changing with the temperature? Is it possible that the velocity of light may vary with temperature, apart from any relation to material substances, or is the foregoing relationship dependent upon some molecular function like that suggested, that is "molecular domain?"

It seems impossible to answer the first part of this question. The second part can be judged by analogy, which would appear to suggest that a molecular function is more probable. Thus, one might expect that the kinetic energy of the particles is the property directly increased by rise of temperature, and

that many or all other properties of the molecule are consequential upon that. The apparent volume of course increases. That fraction of the volume which is measured by

$$\frac{\mu^2-1}{\mu^2+2}v, \text{ or } \frac{\mu-1}{\mu}(v-\beta)$$

also increases, whatever it may be called. This constant fact appears to be a decided argument in favour of these expressions, giving "domain" and not "volume of matter" simply. But again, if the plea for "domain" be granted, there ought to be increase, not only when the liquid is heated, but also when it is changed into a vapour. This is actually the case for $\frac{\mu-1}{\mu}v-\beta)$, the value of which increases in the ratio 1 to 1·4 or 1·5. This variability may be compared with that found by van der Waals for his constant "b" ('Continuity &c.', Phys. Soc. translation, p. 409).

Correction.

On page 286 of this volume (xiii.) of the 'Proceedings' in the report of the discussion upon Dr. Larmor's paper, Professor Lodge is represented as criticising Dr. Larmor's summary of Herr Wiener's paper. It appears that Professor Lodge intended to refer to asummary made some time ago by Herr Wiener and not by Dr. Larmor.

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X. & XI. Illustrative of Mr. H. F. W. Burstall's Paper on the Measurement of Cyclically Varying Temperature.

PHYSICAL SOCIETY OF LONDON.

ABSTRACTS OF PHYSICAL PAPERS

FROM FOREIGN SOURCES.

DECEMBER 1895.

GENERAL PHYSICS.

743. *Meteorites.* **H. Moissan.** (C. R. 121. pp. 483–486, 1895.)—The discovery by Friedel of transparent black diamond in the meteorite of Cañon Diablo (C. R. 115. p. 1037) has induced the author to investigate a number of meteorites in order to prove if, and in which form, carbon is contained in them. After having made a very careful analysis of six different meteorites, he arrived at the following conclusions:—Some of the holosiderous meteorites, as for instance *caillite*, an iron-meteorite of Toluca-Xiquipilso in Mexico, do not contain carbon at all; in several others carbon is met with in the form of amorphous carbon only, or in combination with graphite; one of the analysed samples, namely the meteorite of Novy-Urej, Krasnoslobodsk, in the province of Pensa in Russia, contained carbon as black, but with the exception of one very small particle, not transparent diamond, as has before been proved by Terofeïeff and Latchinof. Only a single meteorite, the one of Cañon Diablo, is known to contain all the three varieties of carbon, viz. transparent black diamond, graphite, and amorphous carbon. S. R.

744. *Synodic and Anomalistic Revolutions of the Moon and Barometer-Curves in Spring.* **A. Poincaré.** (C. R. 121. pp. 468–471, 1895.)—A tabular paper, referring to the three lunar months, March 9 to April 6, April 7 to May 6, May 7 to June 4, 1883. Data are given particularly for the second month. When the moon is in northern declination, a depression begins 4 hours before the moon crosses the meridian; 2 hours later, the pressure is normal; the passage is marked by a minimum of 5 mm.; 2 hours later, the pressure is normal again; and then

follows a maximum. For southern declination, the meridian depression of 2 or 4 mm. is flanked by two rises; at the antipodes there is a rise between two depressions. For the syzygies: on the meridian of the sun and for several sectors on both sides, a depression of from 2 to 5 mm. is noticed, lasting from the day preceding to the day following; the moon has the opposite effect. For the quadratures: great depression over at least 90° in rear of the sun; rise in the meridian of the moon and the antipodal point, unless the southern declination is slight. The paper states momentous days of the lunar month for different Oceans. The 27th is everywhere changeable; new moon is unfavourable for the Atlantic. The influences of apogee and perigee are traced. H. B.

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745. *Spheroidal State and Capillarity.* **E. Gossart.** (Ann. Chim. et Phys. 4. pp. 391–423, 1895.)—The article has for its object the testing of a theory of the spheroidal state, which attributes the well-known phenomenon to no mysterious causes, but to simple capillary actions. The author considers three phenomena which are, according to his view, capable of explanation by the same principles. He considers (1) the well-known phenomenon of drops existing on hot plates at temperatures much above the boiling-point of the liquid concerned, when the spheroidal state is said to be produced; (2) the *same spheroidal state* produced in a liquid medium on a well-polished plate at *ordinary temperatures*; he calls this the spheroidal state produced in a wet way (*caléfaction par voie humide*); (3) the rolling drops often observed by chemists when filtering.

Under (1) he shows that there is nothing fixed about the temperature of the plate which is necessary to produce the spheroidal state, but that it varies with the degree of polish. For example, he cooled a well-polished gold plate, on which was supported a drop of water, to a temperature of 80° C. without disturbing the spheroidal state.

Under (2) he states that Quincke has already observed the phenomenon, but not under the same aspect as considered in the article. By electrical and other means he shows that there is a distinct interval between the drop and its support, so long as the spheroidal state continues; but as soon as it takes the lenticular form, then the continuity between it and the support becomes complete.

Section (3) is perhaps the most ambitious. He produces the drops by allowing the liquid of which they are composed to fall on another liquid that is contained between two vertical plates which meet at a small angle; after formation, the drops roll down the incline. He attributes the production and continued existence of the drops to the generation of a supporting layer of vapour. He studies the effect of surface-tension, temperature, and viscosity; shows that only liquids which have the same chemical properties will roll on one another, and hence uses the phenomenon to analyse

certain solutions. He has one solution of a known strength; and to determine the unknown strength of the other solution he dilutes one or the other in an organised manner until the observations indicate similarity of composition. A. Gs.

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746. *Thermopiles for Meteorological Instruments.* **P. Czermak.** (Wied. Ann. 56. pp. 353–359, 1895.)—The author recommends very fine wires, 0·1 mm. thick, 2 or 3 cm. long, the junctions being covered with soot or soot and shellac, as preferable to the far too sluggish thermometers and the oversensitive bolometers. Two copper cylinders are fixed in wood: each has a flange with a binding-screw; the other ends are conical, the interiors hollow and filled with water. The wires, copper and constantan, are soldered to the pointed ends. A thermometer in the one tube indicates the slow variations, the thermo-couple the rapid changes of 1·5 seconds and more. The author constructed his galvanometer as follows:—To a mica disc are fixed a silvered glass of 6 sq. mm. surface and five little magnets, pieces of watch-spring 3 mm. long. The system has a period of 0·7 sec., and is well damped by copper masses. The instrument has been devised for studying the "Föhn"; it has indicated variations of 18°, 2 m. above the soil, with a mean temperature of 10°.

His second instrument is a relative actinometer. It consists of two concentric brass tubes, completely divided into two half-cylinders by two ebonite bars, and closed below by a thick copper plate, and above by a cover. In the bottom three thermo-couples are fixed, connected in parallel, and bridging over the insulated halves. The annular space is filled with water, and a thermometer inserted. When an aluminium screen fixed above is turned aside, the light passes down the inner hollow to the thermopile. The back of the thermopile is covered by a paper tube, closed by a plate of rock-salt. Thirty divisions correspond to one degree. The instrument seems suitable, but exact tests have not yet been made. H. B.

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747. *Bizio and the Theory of Solution.* **M. Bellati.** (N. Cim. 4. 2, pp. 49–58, 1895.)—Van't Hoff's theory of solution—that the condition of a substance dissolved in a solvent is analogous if not identical with that of a gas, the solution-pressure in the one case corresponding to the gaseous pressure in the other—was, though van't Hoff was himself original in his work, anticipated in its main lines by Bizio. In 1845 he wrote ("Sopra l'azione della calce entro l'acqua conducente in che consiste la Soluzione," I. R. Istituto Veneto di Scienze, Lettere ed Arti, 17 Feb., 1845, and republished in 'Raccolta fisico-chemico italiana dello Zantodeschi,' vol. ii. pp. 257–272):—"I look upon the substance dissolved as an elastic vapour diffused in the liquid, and forming there as every vapour forms amid the air, there being no difference other than that the

latter rises and keeps itself up by its own tension, while that of the former is insufficient, and needs the presence of a body of suitable density. . . .," as the clouds float in the air. Bizio kept this idea before him; and he claims its importance in one of his latest papers ("La soluzione senza soccorso di affinità chimica," Mem. Ist. Venet. ix. pp. 79–111, 1860). While van't Hoff looks to dilute solutions, Bizio dealt with saturated solutions, which he equates with saturated vapours. Gay-Lussac had already noted this analogy (C. R. 8. pp. 1000–1017, 1839; Ann. de Chim. et de Phys. 70. 1839); but he explained solution by chemical affinity. Bizio protested against this, on the ground that affinity should cause heat: the true analogy was evaporation, accompanied by cooling (see his paper of 1845); and more than this, the state of a body in solution was the elastic or vapour state. He thought saturation was reached when the internal pressure of the liquid was in equilibrium with the pressure of the molecules of the substance dissolved; that heat raised the internal pressure of the liquid, and that more of the substance dissolved might then be taken up before equilibrium was reached; and he thought lime was precipitated from heated lime-water because the water-molecules expanded more than the lime-molecules. He looked upon the green colour of a concentrated solution of chloride of copper, and the blue of a dilute, as due to dilated molecules in the former case as compared with compressed molecules in the latter; and showed that the pressure necessary in order to bring about the green colour might be secured at ordinary temperatures by the addition of common salt. If on heating a dilute solution the water-molecules expanded more rapidly than the copper-chloride molecules, the colour ought on this view to become green; which is what takes place. The circumstance that chloride of copper in quantity just sufficient to make an aqueous solution green will confer the same colour on six or more times the volume of alcohol, he explained by the greater repulsive force of alcohol (see also Atti Ist. Venet. 1850–51, pp. 53–55). In the Atti Ist. Venet. (3) 1. pp. 129–148, Bizio compares cooling on dilution to cooling of a gas on expansion (see also Mem. di mat. e di fis. della Soc. ital. delle Sc. 25. parte 2, pp. 128–154, 1855). He explained the colour of solutions of iodine on the same lines (Mem. Ist. Venet. 9. p. 110, 1860). Bizio limited himself, however, to the solution of solids in liquids, and thus failed to attain generality of statement; besides which, he had rendered himself unpopular by his attacks on the imponderables and on the mechanical units then employed. His ideas as to chemical dynamics are a good deal cleared up if, instead of repulsive force, we read molecular energy; but there still remain mistakes and inconsistencies, which do not, however, deprive him of the merit of being a precursor in the theory of solution as well as various other dynamical concepts of modern science.

A. D.

748. *Problem of the Motion of a Solid in an Infinite Liquid.* Note by **E. Trevisan.** (N. Cim. 4. 2, pp. 175–177, 1895).—The author refers to Kirchhoff's solution of the equation of motion of a rigid body in an infinite liquid as capable of complete integration whenever the kinetic energy of the system consisting of the body and the liquid admits of expression in the form

$$2T = a_{11}(u^2+v^2)+a_{33}w^2+b_{11}(p^2+q^2)+b_{33}r^2,$$

in which $u\,v\,w$ are the components of the translation-velocity, and $p\,q\,r$ those of the rotation of the body referred to any axes fixed in the body; and Kirchhoff's nineteenth lecture is referred to as showing that this will always be the case if the body is symmetrical with respect to two pairs of planes passing through a right line and orthogonal to one another. In the present paper the author claims to prove that the kinetic energy will assume Kirchhoff's form in the more general case that the body is symmetrical with respect to two pairs of planes passing through a right line, whether orthogonal to one another or not.

The most general form of the expression for the kinetic energy involves 21 coefficients—viz. 6 for the squares and products of $u\,v\,w$, 6 for the squares and products of $p\,q\,r$, and 9 for the products of the form $up\ uq$ &c. Taking the intersection of the two planes for axis of z, and one of the two planes for that of xz, the conditions of symmetry reduce these to 12, viz.:—

$$\begin{aligned}2T = {} & a_{11}u^2+a_{22}v^2+a_{33}w^2+2a_{13}uw \\ & +b_{11}p^2+b_{22}q^2+b_{33}r^2+2b_{13}pr \\ & +2c_{13}uq+2c_{24}vp+2c_{26}vr+2c_{36}wq.\end{aligned}$$

And now, by a transformation of coordinates, taking the other plane of symmetry for that of xz, it is shown that the expression for 2T can be reduced to Kirchhoff's form. S. H. B.

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749. *The Mounier Observatory; Venus.* **Perrotin.** (C. R. 121. pp. 542–545, 1895.)—The Mounier Observatory, 2741 m. above sea-level, has, by the munificence of Bischoffsheim, been fitted out as an annexe to the Nice Observatory, with astronomical and meteorological instruments. There is a stone building, connected by a gallery with the house, a revolving cupola, an equatorial of 35 cm. aperture, and a shed. A telephone-line of 8 km. length, also supplied by Bischoffsheim, joins the observatory to the nearest railway-station. The installation was completed in August, when Venus was already a crescent of which only the border could be examined. Dark lines seemed to start, as in 1890, from the border and form triangular or polygonal islands or deltas on the illuminated part. But the dark band from horn to horn, which in 1890 these lines seemed to join, was absent. The author thinks, however, that the band could not have been seen, if present, as the planet was much nearer conjunction this year. The horns

always appeared the same, making allowance for the effects of different altitudes at different times. As in 1890, a large white spot was noticed about 10° from the northern horn. This spot did not change. These observations, therefore, support Schiaparelli's view that Venus revolves very slowly about her own axis. The spot would also appear immovable if it were close to the axis, and the axis almost at right angles to the plane of the orbit. H. B.

750. *Elastic Properties of Metals.* **M. Cantone.** (Rend. Acc. Lincei, 4. 2, pp. 31–38, 1895.)—This paper deals especially with the peculiar accommodation phenomena shown by tempered nickel. When the forces applied in a bilateral cycle are small, the deformations follow the same laws as in brass and other metals, but when the variations are started from a large initial torsion, the extreme and the permanent deformations increase, so that at each return to the original maximum force the torsion is greater than it was at the beginning. If such behaviour were common to all the metals, it would be easily explained on the assumption that the first forces acting in one sense brought about the rupture of some molecular groups, imparting to a number of particles the properties of a liquid, and that the subsequent intervention of forces acting in the opposite direction, where the maximum deformation is not too great, does not reconstitute these groups, but tends to give to the body a more homogeneous structure by making the free molecules re-enter the sphere of attraction of the remaining ones. But when the initial angle of torsion is very great, it is possible that the first alternations, instead of repairing the ruptures caused by distortion from the original state, bring about more ruptures. This would be borne out by the fact that in tempered nickel there is greater subsequent action after each cycle, and hysteresis becomes more and more pronounced, until a state of equilibrium is reached between the particles liberated and those entering the sphere of attraction of neighbouring ones. But in every case where the torsional force is carried to a high value, a continuous displacement of particles sets in. This may or may not be due to the body acquiring the character of a fluid in some parts, but anyhow a state of equilibrium becomes impossible at a certain point and the basis of statical processes becomes smaller. In very ductile metals this limit is relatively low. Hence at a certain point the behaviour of all metals will be that observed in tempered nickel, and the latter will be no longer abnormal. E. E. F.

751. *Coalescence observed in Soft Crystals.* **O. Lehmann.** (Zschr. phys. Chem. 18. pp. 91–96, 1895.)—When potassium oleate is added to a drop of alcohol on the object-glass of a microscope and warmed, so that most of it dissolves, it separates out on cooling in the form of acute octahedric crystals of the tetragonal system, whose edges are a good deal rounded; but their structure may be identified by polarised light. Now when two such crystals touch, they grow together: slowly turn round till the axes of the

two octahedra are parallel, the surface of contact spreading meanwhile; and eventually a single homogeneous crystal is formed; just as two oil drops floating in dilute alcohol of the same density coalesce under the influence of their surface-tension. It appears, then, that a similar coalescence takes place in these very soft crystals, under the combined influence of the surface-tension and the forces tending to the alignment of the molecules. The author gives drawings showing the details of the process. R. A. L.

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752. *Apparatus for the Determination of Molecular Weights by the Boiling-point Method.* **W. R. Orndorff** and **F. K. Cameron.** (Am. Chem. Journ 17. pp. 517-531, 1895.)—One of the flasks sold for the jacket in Victor Meyer's vapour-density method is cut down to a length of 30 cm., and in it is placed 30 or 40 grams of platinum pellets made of platinum-foil. The flask is closed by a cork through which pass the thermometer and a wide tube to act as a condenser. One of Beckmann's adjustable thermometers is used, and to prevent the sticking of the mercury-column the head of the thermometer is tapped by a small electro-magnetic hammer. To aid in condensing the vapour of the liquid, a wrapping of copper-gauze is clamped around the upper part of the flask. Asbestos-screens are used to prevent draughts. To make a determination, the weighed quantity of solvent is boiled for about an hour till the thermometer has adjusted itself. Then the substance is introduced as a compressed pellet, and in 2 or 3 minutes readings can be taken. Six or eight determinations can then be made in about thirty minutes. Test experiments are made with naphthalene, anthracene, triphenylmethane, and acetanilide dissolved in various solvents. The results for the same solvent are very concordant with one another, but with different solvents there is a marked difference. S. S.

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753. *Density Determinations of extremely Diluted Solutions.* **F. Kohlrausch.** (Wied. Ann. 56. pp. 185-200, 1895.)—With the help of immersed bodies, density determinations can be made to the 7th decimal, provided we can control the temperature, which is possible for aqueous solutions and glass floats at about 6°, where glass and water have approximately the same expansion coefficients. For silver floats, the temperature might vary between 6° and 10°. A beaker, 38 cm. high and 16 cm. wide, covered with felt has been used, containing 5 litres of water. The glass float weighed 916 g., and could not be suspended by one cocoon-thread. A strand of several threads gave trouble by capillary absorption; a smooth platinum wire became unevenly wetted, one coated with spongy platinum likewise. But when heated for a moment by a small Bunsen burner, the wire became almost uniformly and completely wetted. The meniscus forming round this wire was not the same for different liquids, but the variation was of no consequence. As the float consisted of thick glass, the temperature had to be

controlled most carefully. The tests concern sugar, used for preliminary work also, sulphate of magnesia, acetic acid, and sulphuric acid. The molecular volume of the sulphuric acid decreases considerably with higher dilution; Nernst and Drude have sought to establish a connection between this contraction and free ions. According to previous experiments, substances whose molecular volumes are little affected by dilution may, in stronger solutions, be good conductors (HCl, NaCl), or poor conductors (sugar, acetic acid). It follows that the molecular contraction of acids, like the conductivity, increases with continued dilution to a maximum, and decreases afterwards. This reversal needs further study. The hydrogen compounds may interact with the water or with the impurities. The water used had a conductivity of 1·5 or 2·5 10^{-10} Hg. Greater purity could hardly be obtained experimentally with beakers of 5 litres capacity. Another avoidable source of error is, under these circumstances, not regarded as so very important. The large stirrer made of nickel was attacked by the agitated sulphuric acid, and, once slightly corroded on the surface, seemed to offer less resistance even to the diluted acid. The molecular volume ϕ is calculated from m, gramme equivalent per litre; s, specific gravity; A, equivalent; $\phi = A - 1000\ (s-1)/m$. For sugar, ϕ decreases very slowly on copious dilution; for acetic acid also, but there is a reversal at $m = 0{\cdot}001$; for sulphuric acid and sulphate of magnesia, the changes are much more marked, the reversals less striking. The experiments were made at 6°; Hallwachs had worked at 18°. A water, less pure than the water usually employed, had a conductivity of $5{\cdot}10^{-10}$ and a specific gravity of 1·000007.

H. B.

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754. *The Diurnal Variation of Relative Humidity.* **D. Eginitis.** (C. R. 121. pp. 574–575, 1895.) *The Double Diurnal Oscillation of Relative Humidity.* **A. Angot.** (C. R. 121. pp. 595–596, 1895.)—In general, the relative humidity diminishes as the temperature increases, and there is, therefore, a maximum in the morning and a minimum in the evening. The first author notifies that at the Observatory of Athens there is an additional maximum towards 7 or 8 in the evening, and another minimum two to four hours later: he endeavours to explain the phenomena solely by considering the variations of the temperature and absolute humidity.

The second author attributes the phenomena to sea- and land-breezes, and states that similar observations have already been made, for example by Bijourdan at Joal, on the east coast of Africa; there the second maximum takes place between mid-day and three o'clock in the afternoon, agreeing with the deduction from the records of the direction of the wind. He also states that places far inland, on plains or plateaux, will not be subject to such a variety of perturbations.

A. Gs.

755. *Change of Volume of Thallium in the act of Fusion and the Thermal Dilatation of the Liquid produced.* **G. Pacher.** (N. Cim. 4. 2, pp. 143–155, 1895.)—Toepler, in 1894, and Omadei, in 1891, obtained certain values for the variation in volume of thallium when it changes from the solid to the liquid state, which are divergent.

Toepler's method consists in placing the solid thallium in a bulb, containing olive-oil, from which a graduated tube proceeds, and heating the apparatus by suitable means above the melting-point of the substance being examined. This method has the inconvenience that bubbles are formed by the action of the hot oil on the metal. The author finds that the action of the air on the products of volatilisation is a serious cause of irregularities, and improves the apparatus by widening the graduated tube into a sort of bell-funnel at the top, and placing over the junction a thimble-shaped vessel containing oil, the use of which is to act as a sort of trap. The top of the funnel is fitted with a cork, through which a fine glass tube passes.

Omadei's method consists in filling the bulb and part of the tube with solid thallium; on endeavouring to apply it, the author found that the oxide of thallium produced difficulties, and ultimately changed the apparatus, so that it is not very dissimilar from the ordinary form of cryophorus.

The thallium may be supposed to be put in the lower bulb and covered with distilled water free from air. The lower bulb and tube is heated and the upper bulb placed in ice. In this way the thallium is examined in an atmosphere of pure water, under the pressure exerted at 0° C.

The results obtained by the various observers are indicated in the table given below, where K_λ represents the increase in volume in c.c. when 1 gram of thallium is melted, Δ the percentage change in volume when melting occurs, and α the mean coefficient of dilatation of the liquid thallium between the melting-point and about 30° above.

	Omadei's Results.	Toepler's Results.	Modification of Omadei's Method.	Modification of Toepler's Method.
α	0·000150	——	0·000128	
Δ	4·32	——	3·22	
K_λ	0·00376	0·0027	0·00276	0·00249

A. Gs.

756. *Elastic Hysteresis of Metals.* **M. Cantone.** (Rend. Acc. Linc. 4. 2, pp. 3–10, 1895.)—Wires were subjected to torsional stresses gradually increasing in amount. The molecular yielding increased with the torsion, but this produced a lag when the direction of variation of force was reversed. This may therefore be accurately described as elastic hysteresis. When the force

varies between zero and a certain positive amount, the cycle is described as unilateral ; when it varies between positive and negative values, as bilateral. Starting from a permanent deformation due to a certain maximum torsion, it is found that when any smaller force is applied, the force and the deformation are proportional, the constant being very nearly equal to, but slightly greater than, that shown by a wire starting from the initial stage. The best way to bring the wire back to the initial stage is to twist it backwards and forwards through decreasing angles. E. E. F.

757. *Evaporation and Theories of Capillarity.* **G. Van der Mensbrügghe.** (C. R. 121. pp. 461–462, 1895.)—The author objects, as against the usual theories of capillarity based on equilibrium—(1) that the surface-film must diminish in density from within outwards, else there would be an abrupt break of continuity; (2) that the loss of weight by evaporation cannot be neglected, particularly in soap-bubble films, and the volume can therefore not be considered invariable ; (3) that the continuous renewal of the surface-film precludes equilibrium in that film. Referring to 'Bull. de l'Acad. roy. de Belg.' 3e série, t. xxvi. pp. 37–71, and 'Ann. de la Soc. Scientif. de Bruxelles,' t. xviii. 1° partie, Jan. 1894, he says that the progressive diminution of density of the surface-film from within outwards explains at the same time the evaporation and the least-surface forces or superficial tension.

A. D.

758. *The Mont Blanc Observatory.* **J. Janssen.** (C. R. 121. pp. 477–483, 1895.)—On September 26, Janssen had himself taken up to the top in order to see about the Richard's meteorograph, which had stopped, and the mounting of the polar siderostat. Starting from Chamounix, they spent the first night at the Grands Mulets, the second at the Rocher-Rouge, and arrived at the top after two hours' march on the third day. During the remarkably clear weather, Janssen, in being up, could watch the air currents and the formation of clouds which, however, offered no abnormal features. To refix the meteorograph, plates were frozen to the ice, and the instrument shifted over by means of its screws ; the cold will probably arrest the instrument again. At noon, the temperature on the top was about 0, the dew-point −18°. A Duboscq spectroscope with two prisms showed in this extremely dry and rarefied atmosphere no absorption-bands of water-vapour at D and C, and a doubtful indication at *a*. Further tests as to *a* will be necessary ; but D and C must belong to the terrestrial atmosphere. The descent down to Chamounix was accomplished in 10 hours. 11 to 9 P.M. on the following day. The whole observatory, as examined from Chamounix, has moved a little in this direction. But as the settling had already taken place in 1893 and 1894 and as the original position can be regained, Janssen recommends observatories built on the eternal snow. H. B.

759. *Rotation of a Body within which exist Cyclic Systems.* **V. Volterra.** (Rend. Acc. Linc. 4. 2, pp. 93–97, 1895.)—The author propounds an extension of certain former memoirs of his ("Sulla teoria dei moti del polo terrestre;" "Sul moto di un sistema nel quale sussistono moti interni stazionari;' "Sopra un sistema di equazioni differenziali; un teorema sulla rotazione dei corpi," Atti della R. Acc. di Torino, 1894, 1895). The following theorem is derived from the former memoirs:—"When a system gyrating about a fixed point is not affected by any couple, and has internal isocyclic motions with constant parameters, the components of rotation are elliptic functions of the time, and the cosines of the angles which the principal axes of inertia make with fixed axes are uniform functions of the time." Then he states that if the system be left to its own inertia the internal motions will change in intensity, and will not remain isocyclic, at all events if the principal moments of inertia are unequal. He concludes that there is mutual action between the rotation of a body and its internal cyclic motions. He then proposes the general problem: A system in which exist internal cyclic motions of any kind with constant parameters is left to its own inertia: required to find the rotation of the system, and according to what laws the energy of the cyclic motions will vary in virtue of the mutual action which these motions exert on one another. Of this problem he states the solution, but in notation which will not be intelligible without reference to the former memoirs. The mathematical work is promised for a future number. S. H. B.

760. *Electrolytic Conductivity of Aqueous Solutions; i's Connection with the Temperature.* **G. Jäger.** (Wien. Ber. 104. 5, part 2 *a*, pp. 408–425, 1895.)—According to the author, a simple explanation of the lowering of the freezing-point of a liquid by dissolving a foreign substance in it, may be obtained by supposing the energy of the liquid to be increased. This acts in the same way as if the temperature of the liquid were raised, so that the solution must be cooled down in order to show the same properties as the original solvent. For example, the maximum of density of an aqueous solution will be found at a lower temperature than with pure water. Assuming that the electrolytic conductivity of a solution depends on the number of ions in it, and on the frictional resistance with which they meet in passing through it, and that the latter is proportional to the viscosity of the solvent, he calculates, with the help of the above ideas, the temperature coefficients of the electrolytic conductivity of aqueous solutions. Neglecting various factors, such as the change produced by temperature in the dissociation of the salts dissolved, and the effect of changes of concentration on the resistance offered by the solutions to the passage of the ions through them, the author arrives everywhere at an agreement between theory and experiment. T. E.

LIGHT.

761. *Achromatic Interference.* **W. König.** (Wied. Ann. 55. pp. 1–43, 1895.)—The author discusses, experimentally and mathematically, the non-coloured effects produced, through overlapping of fringes, when the source of light in diffraction-experiments is itself a spectrum or a part of one. A. D.

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762. *Electro-optical Researches with Polarised Light.* **J. Elster** and **H. Geitel.** (Berl. Ber. 11. pp. 209–216, 1895, and Wied. Ann. 55. pp. 684–700, 1895.)—The photo-electric current from a kathode exposed in a rarefied gas to suitable illumination has been shown to depend upon the direction of the optical vibrations with respect to the kathode-surface, and to reach a maximum when the plane of polarisation of the incident light is perpendicular to the plane of incidence, and a minimum for a position at right angles to this. The further prosecution of this subject naturally divides itself into two parts. One may ask (1) "According to what law does the photo-electric current vary when the plane of polarisation of the incident light is rotated about the incident ray as axis?" or (2) "What is the relation between the intensity of this current and the angle of incidence of the illuminating beam?" The present paper is chiefly confined to the first of these questions, only a few preliminary contributions towards an answer to the second having been yet obtained. The surface generally used for this research was that of a liquid alloy of sodium and potassium enclosed in a thin rarefied glass bulb of 5 cm. diam., in the upper half of which was the anode of platinum wire. The source of light was an incandescent disc of zircon heated by a flame of coal-gas and oxygen. The beam passed through the usual collimating arrangement and a large Nicol's prism capable of rotation. The liquid alloy and the anode were in circuit with a galvanometer and a battery of Leclanché cells of an E.M.F. of about 450 volts. As the polariser was turned through a complete revolution, the galvanometer showed two maxima and two minima. The former occurred when the principal section fell in the plane of incidence, the minima in the two positions at right angles to the above. If one measures the angle of rotation, α, of the prism from the position of maximum current (for which the plane of polarisation of the incident light is at right angles to the plane of incidence, and consequently the electric displacements in the plane of incidence), then the photo-electric current, I, can be expressed as follows:—

$$I = A\cos^2\alpha + B\sin^2\alpha,$$

where A is the maximum value of the current for $\alpha = 0$, and B is the minimum value for $\alpha = 90°$. The following are specimens of the results obtained, showing the close agreement between the experiments and the formula deduced from them:—

Bulb I. Half full of alloy of potassium and sodium.

A. Angle of incidence = 70°.							
Azimuth α	0	15	30	45	60	75	90
Current (observed)	149·6	138·0	111·0	74·6	38·9	12·7	3·2
Do. (calculated)....	147·3	137·6	111·3	75·2	39·3	12·9	3·2
Difference	+2·6	+0·4	−0·3	−0·6	−0·4	−0·2	
B. Angle of Incidence = 66°.							
Current (observed) ...	144·0	132·5	107·0	72·3	38·3	12·5	4·0
Do. (calculated)...	141·6	132·4	107·2	72·8	38·4	13·2	4·0
Difference	+2·4	+0·1	−0·2	−0·5	−0·1	−0·7	
D. Angle of Incidence = 23°.							
Current (observed) ...	96·8	91·8	79·7	63·3	42·9	30·0	28·1
Do. (calculated)...	97·2	92·5	79·9	62·6	45·4	32·7	28·1
Difference	−0·4	−0·7	−0·2	+0·7	−2·5	−2·7	

E. H. B.

763. *Anomalous Dispersion of Solid Fuchsin and other Dye-stuffs.* **A. Pflüger.** (Wied. Ann. 56. pp. 412–432, 1895.)—The method adopted was that of Kundt for the refractive indices of the metals. Prisms of angle 40″ to 150″ were obtained by evaporation of an alcoholic solution of the colour on glass plates. The deviation produced by these, for certain spectrally defined rays of light, was measured on the spectrometer. The prisms were transparent enough to measure the refractive index even in the deepest part of the absorption-band. Fuchsin, Cyanin, Hofmann's violet, Magdala red, and Malachite green were used. The results were strictly in accordance with Helmholtz's theory, the refractive index diminishing regularly, in going up the spectrum through an absorption-band, and in two instances its value fell to less than unity. For strontium blue, Fuchsin gives $\mu = 0{\cdot}83$, so that it should show total reflexion for an angle of incidence of 56°. The author finds, however, that a glass plate covered with a parallel-sided layer of fuchsin, remains transparent when the angle of incidence is 87°, and concludes that the law of sines does not hold good in the case considered. R. A. L.

764. *The Equations of the Electromagnetic Theory of Light derived from the Data of Optical Experiments with Crystals.* **E. Ketteler.** (Wied. Ann. 55. pp. 525–539, 1895.)—This is a mathematical paper chiefly concerned with discussing the rival optical theories of Neumann, Fresnel, and the author. The analysis is based upon the following equations :—

$$\left.\begin{aligned} \frac{\partial^2 L}{\partial t^2} &= \Delta_2 X - \frac{\partial}{\partial x}\left(\frac{\partial L}{\partial x}+\frac{\partial M}{\partial y}+\frac{\partial N}{\partial z}\right), \quad \cdots\cdots \\ \frac{\partial X}{\partial x}+\frac{\partial Y}{\partial y}+\frac{\partial Z}{\partial z} &= 0. \end{aligned}\right\} \quad (1)$$

$$\left.\begin{aligned} \frac{\partial^2 L}{\partial t^2} &= \Delta_2 X - \frac{\partial}{\partial x}\left(\frac{\partial X}{\partial x}+\frac{\partial Y}{\partial y}+\frac{\partial Z}{\partial z}\right), \quad \cdots\cdots \\ \frac{\partial L}{\partial x}+\frac{\partial M}{\partial y}+\frac{\partial N}{\partial z} &= 0. \end{aligned}\right\} \quad (2)$$

and

$$L = n_1^2 X, \quad M = n_2^2 Y, \quad N = n_3^2 Z, \quad \cdots\cdots\cdots \quad (3)$$

where n_1, n_2 and n_3 are the three principal indices of refraction of the crystal. For the first of these equations the author claims credit, (2) and (3) being from Maxwell. E. H. B.

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765. *Ultra-Violet Aluminium Wave-lengths.* **C. Runge.** (Wied. Ann. 55. pp. 44–48, 1895.)—With experimental precautions described, the following wave-lengths were determined with a Rowland grating and photographic apparatus :—

At 760 mm. and 20° C..	1854·09	1862·20	1935·29	1989·90
In vacuum	1854·77	1862·81	1935·90	1990·57
Cornu	1852·2	1860·2	1933·5	1988·1

Cornu's measurements were made in 1881 with a Rutherford grating, and have to be raised about 16 per hundred thousand on account of their being based upon an absolute measurement for the D-line, which is below that given by Rowland (Standard Wave-lengths, Phil. Mag., July 1893). The author's mean error is less than 0·014. A. D.

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766. *The Accuracy attainable in Actinometric Observations.* **R. Savélief.** (Ann. Chim. et Phys. 4. pp. 424–429, 1895.)—The author records his experiments on Violle's actinometer. He uses two examples of the instrument, one large and one small. He finds that with careful observation the smaller pattern gives equally good results with the larger. He describes at length the loss of heat along the stem of the thermometer : he compares the behaviour of bulbs covered with platinum-black and lamp-black respectively, giving preference to the former only on the ground

that the operation of blackening is less risky in inexperienced hands. There is next considered the effect of the angle of incidence on the absorption of rays by a black surface. Lastly, the author concludes that the necessary corrections are inconsiderable, with the exception of the effect of the thermometer-stem, which can be determined with sufficient accuracy and that, therefore, the instrument is in all respects trustworthy. A. Gs.

767. *Fluorescence of Organic Compounds in the Gaseous, Liquid, and Solid States.* **E. Wiedemann** and **G. C. Schmidt.** (Wied. Ann. 56. pp. 18–26, 1895.)—In order to test the fluorescent properties of organic vapours, the substances under examination were introduced into thick-walled glass bulbs 6 to 8 cm. diam., which were exhausted and sealed. The source of light was either the electric arc or the sun. The following fluorescent effects were observed:—

Substance.	Colour.
Anthracene	Deep blue.
Anthraquinone	Blue.
Indigo	Pale violet.
Naphthalene	Very pale violet.
Naphthazarin	Gorgeous reddish brown.
Quinine	No fluorescent colour.
Diphenylamine	
Naphthoquinone	

The luminous effects of various organic substances exposed to the electrical discharge in a special form of Geissler tube was then observed, with the following results, the noteworthy feature being the continuous spectrum often exhibited:—

Substance.	Colour.	Limits.	Maximum.	Colours present.
Anthracene	Bright blue.	420–500 $\mu\mu$	450 $\mu\mu$	
Quinone	Golden yellow.	.....	.....	Red, yellow, green.
Anthraquinone	Greenish blue.	420–540	425	
Naphthalene	Bright blue.	435–545	490	
Napthoquinone	Green.	475–580	535	
Naphthazarin	Reddish brown	.....	.....	Red, yellow, green.

The fluorescence of liquids was investigated by subjecting them to the action of negative rays in a vacuum of several millimetres.

Aniline showed a blue, and diphenylamine a beautiful blue fluorescence. Finally, solid bodies were subjected to the action of the negative rays, the following being a selection of the substances so treated with the effects observed:—

Substance.	Colour.	Afterglow, if any.
Salicylic acid	Bright blue.	A little.
Benzoic acid	Bright green.	,,
Toluidine	Intense yellowish green.	,,
Hydroquinone	Blue.	Tolerably long.
Naphthalene	Intense white.	
Anthracene	Green.	
Paraffin	Pale blue.	
Anthraquinone	Greenish yellow.	Bright yet quickly fading.
Nitrotoluidine	No fluorescence observable.	
Indigo		
Menthol		
Alizarin		
Tannin		
Purpurine		
Eosin		
Citric acid		
Malic acid		

E. H. B.

HEAT.

768. *Heat from Solidification in Solutions.* **O. Tumlirz.** (Wien. Ber. 104. 3. Part II *a*. pp. 245-267, 1895.)—If two liquids B, A, whose normal freezing-points are t_2, t_1, where $t_2 > t_1$ are mixed at a temperature higher than t_2 in the mass-ratio $m : 1$, their behaviour on cooling depends on the value of m : if m exceeds a certain value m_1, B will begin to solidify out at a temperature $t_2 - \Delta$, where Δ is the less the greater m, the remaining liquid being then a saturated solution of B in A ; but for $m < m_1$ the mixture remains entirely liquid till $t_1 - \Delta'$ when A begins to solidify out, Δ' diminishing with m.

It is then clear that on attaining the composition $m_1 : 1$ the solution will keep this composition on further cooling, so that B and A will freeze out together.

Consideration of a cycle with $m > m_1$, in which the mixture is cooled from t_2 to $t_2 - \Delta$, and then further to $t_2 - \tau$ while B freezes out, the solidified portion and the liquid residue being then separately heated to t_2, where the former is melted and then again mixed with the latter, gives the equation

$$\lambda_S = \lambda_0 - \int_{t_2-\tau}^{t_2} (C_{m-S} - \mathfrak{C}) dt - F(m - S, t_2),$$

where λ_S is the heat liberated by solidification of 1 gm. of B from a saturated solution of B in A at the temperature $t_2 - \tau$, S betokening the portion of m that has frozen out so that the mass-ratio in the solution is $m - S : 1$, C_{m-S} being the specific heat of this solution at a temperature $< t_2 - \tau$, $\mathfrak{C}$ that of B when solid, λ_0 the ordinary heat of fusion of B at t_2, and where, lastly, $\int_0^m F(m, t)\, dm$ denotes the heat emitted when m of B is added to 1 of A at p and t. [This equation depends on the assumption, which is ignored, that the saturation specific heats of the solution and the solid when in contact do not differ from their specific heats at constant pressure when separated.]

A similar cycle with $m < m_1$ gives

$$\Lambda_\Sigma = \Lambda_0 + \int_{t_1}^{t_2} (c - c) dt - \int_{t_1-\tau}^{t_2} (C'_\Sigma - c) dt - G\left(\frac{1-\Sigma}{m}, t_2\right),$$

where Σ is the proportion of A frozen out at $t_1 - \tau$, Λ_0 the heat of fusion of A at t_1, c its specific heat when solid, Λ_Σ, C'_Σ are analogous to λ_S, C_{m-S}, and where $\int_0^n G(n,t) dn$ denotes the heat emitted when n of A is added to 1 of B at p and t.

From the definitions of F and G we easily obtain

$$F(m,t)=\int_0^{1/m} G(n,t)dn - G(1/m,t)/m,$$

$$G(n,t)=\int_0^{1/n} F(m,t)dm - F(1/n,t)/n\,;$$

and since, if c, c', C are the specific heats of A, B and the m-solution and the alteration of volume on mixture is negligible,

we have
$$\int_0^m dm(\partial F/\partial t)=c+mc'-(1+m)C,$$
$$\partial F(m,t)/\partial t=c'-C-(1+m)\partial C/\partial m,$$

and similarly
$$\partial G(n,t)/\partial t=c-C-(1+n)\partial C/\partial n.$$

These results are then applied to mixtures of water (as A) and sulphuric acid, and for $n=1{\cdot}84$, $2{\cdot}09$, $3{\cdot}00$, $14{\cdot}50$ the values $\Lambda_\Sigma=55{\cdot}87$, $61{\cdot}52$, $69{\cdot}20$, $78{\cdot}12$ are found: also to mixtures of water (as B) and ethyl alcohol. In the latter case F (m, t) seems to be a function of t only for all values of m between 0 and $1{\cdot}5$, and to vanish for all higher values, pointing possibly to the formation within the solution of a definite compound; and for $m={\cdot}33$, $4{\cdot}13$, $5{\cdot}84$, $9{\cdot}26$, $11{\cdot}82$, $16{\cdot}10$, ∞, the values $\lambda_s=44{\cdot}51$, $68{\cdot}28$, $73{\cdot}10$, $76{\cdot}12$, $76{\cdot}95$, $77{\cdot}67$, $79{\cdot}24$ are found. R. E. B.

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769. *Specific Heat of Mercury obtained by the Method of Cooling.* **A. Bartoli.** (N. Cim. 4. 2, pp. 135–143, 1895.)—Stracciati and the author, in an earlier work, employing the method of mixtures, found that the Sp. H. of mercury decreases slowly with increase of temperature between 0° and 32°. This result differs from that obtained by Regnault by the method of cooling; and the object of the present paper is to show the cause of the difference, and at the same time to obtain accurate determinations. The author's calorimeter for containing mercury was made of iron, that for water of brass; in the experiments in which accuracy was aimed at, the mercury or water, as the case may be, was kept *continually stirred*. The calorimeters were covered externally with lamp-black, and were placed in a metallic box, with double walls, the most inner wall being lamp-blacked, which could be kept at a temperature of 0° or 100° as desired; the latter temperature being required when the Sp. H. was determined by *heating*. The experiments were not confined to simply one set of apparatus. The results of the third column, in the table given below, were obtained with a mercury-calorimeter whose water equivalent was about 18, and contained about 2400 grams of mercury whilst the water-calorimeter had an equivalent of about 11 grams, and contained about 190 grams of water. The calorimeters involved in the fourth column held respectively 5500 and 450 grams of mercury and water. The quantities of mercury and water used in

the experiments, from which the results given in the third column were obtained, were respectively about 2400 and 1900 grams. The second column contains the Sp. H. of mercury obtained by Stracciati and the author by the method of mixtures. In each case the Sp. H. of water at 15° C. is taken as unity.

Specific Heat of Mercury.

t.	Bartoli and Stracciati.	Method of Heating.	Method of Heating.	Method of Cooling
°				
0	0·033 58	0·0	.....	.....
1	0·033 58	.....	.....	.....
2	0·033 58	.....	0·033 40	.....
3	0·033 58	.....	0·033 37	.....
4	0·033 58	.....	0·033 37	.....
5	0·033 58	.....	0·033 36	.....
6	0·033 58	.....	0·033 36	.....
7	0·033 58	.....	0·033 34	.....
8	0·033 57	.....	0·033 34	.....
9	0·033 57	.....	0·033 35	.....
10	0·033 56	.....	0·033 32	0·03338
11	0·033 56	0·03371	0·033 33	.....
12	0·033 55	.....	0·033 28	0·03330
13	0·033 55	0·03373	0·033 27	.....
14	0·033 54	.....	0·033 25	0·03328
15	0·033 53	0·03371	0·033 26	.....
16	0·033 53	.....	0·033 25	0·03327
17	0·033 52	0·03341	0·033 24	.....
18	0·033 51	.....	0·033 24	0·03322
19	0·033 50	0·03330	0·033 21	.....
20	0·033 49	.....	0·033 22	0·03326
21	0·033 48	0·03354	0·033 20	.....
22	0·033 47	.....	0·033 18	0·03319
23	0·033 46	0·03387	0·033 17	.....
24	0·033 45	.....	0 033 16	0·03315
25	0·033 43	0·03345	0·033 14	.....
26	0·033 42	.....	0·033 10	0·03310
27	0·033 40	0·03331	0·033 06	.....
28	0 033 39	.....	0·033 08	0·03308
29	0·033 37	0·03350	.....	.....
30	0·033 35	.....	.....	0·03301

An inspection of the above table shows that each column indicates diminution of Sp. H. with increasing temperature.—The author also determined the Sp. H. of mercury without stirring the mercury or water, and in this way obtained results like Regnault's; but the most striking divergences were shown when water made viscous with gum-arabic or glue (either of which has no great influence on the Sp. H.) was employed; when the liquid was only stirred at comparatively long intervals, the capacity for heat as determined by the method of cooling appeared about 15 per cent. greater than its true value. A. Gs.

770. *Correction of Metastatic Thermometers.* **Scheurer-Kestner.** (C. R. 121. pp. 553–555, 1895.)—The correction to be applied to the readings of a metastatic thermometer is a function of the quantity of mercury which leaves the lower and enters the upper reservoir. When a certain quantity has passed over, the degrees become smaller in proportion to this quantity. If n degrees of mercury are removed, not only the volume of these n degrees must be added, but the amount by which these would have expanded for the temperature t—*i. e.*, ntd, where d is the coefficient of apparent expansion of mercury. Taking away a degrees, the error is below nad; and when the temperature is n degrees, the error does not exceed $na \times 0{\cdot}0001544$. A metastatic thermometer of Walferdin is right at 0° when all the mercury is in the lower reservoir. On removing 10° we have, when the temperature read is 4°, an error of $4 \times 10 \times 0{\cdot}0001544 = 0°{\cdot}0061$, or a little over a two-hundredth of a degree. E. E. F.

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771. *Determining High Temperatures.* **L. Holborn** and **W. Wien.** (Wied. Ann. 56. pp. 360–396, 1895.)—Le Chatelier's thermo-couples (Pt/PtRh, with 10 per cent. Rh) have been compared with an air-thermometer up to 1450°; after long use, they agree within $\pm 5°$ at 1000°. The thermo-electromotive force is little affected by impurities, such as PtSi, formed from the clay by the reduction through hydrogen, which materially influence the resistance of platinum. For higher temperatures a Deville furnace is used, 40 cm. high, 20 wide, the firebrick walls being 10 cm. thick, heated by retort-carbon pieces of nut size. A pipe of graphite-clay can be pushed through the furnace, above a perforated 1 cm. iron plate. The graphite-clay, 1 cm. thick, supplied by Raum of Nürnberg, bears several tests. Inside is placed a clay pipe, which prevents carbon, gases &c. from attacking the objects or thermo-couples. Within this tube 1720° has been observed; in the closed furnace, without pipe, platinum can easily be fused. As neither the various alloys nor even the purest platinum proved quite uniform, Heräus of Hanau has now supplied a large stock of wire which has been standardised. At the highest temperature, platinum evaporates noticeably, and may suffer from the hydrogen as mentioned. A porous clay pipe allowed sufficient carbon (from the gas) to percolate to the couple, apparently to raise the melting-point of gold by 10°. PtRh couples are therefore used with up to 40 per cent. of rhodium; they are, however, less sensitive than the ordinary couples. Melting-points are determined in two ways. A short piece of the respective wire is soldered to both wires, and the interruption of the current is watched; this can be done in air, *in vacuo*, or in hydrogen. For this purpose the prepared couple is placed in a china tube, glazed outside, both ends of which stick out of the furnace so as to remain cold; here the air-pump and generating apparatus are joined by Kundt's glass springs. Hydrogen is always introduced into a vacuum. The pressure within the

tube being, as a rule, lower than without, the fused glazing is forced into the pores of the tube. When the metal (up to 6 kg. of copper) is fused in a crucible, the thermo-couple is inserted in a long china tube, held slanting like the crucible, and connected above with the pump, &c. The couple can therefore be surrounded by air, hydrogen, or a vacuum, which makes no difference in the indications. When the crucible is itself provided with a long neck, through which the thermo-couple is introduced, the metal can be fused in air, hydrogen, or in a vacuum, and repeated fusions can be made in different atmospheres; the melting-points are not affected either. The paper records many tests, and states averages in another part. Ag, melting-point 965° to 982°, mean 971°; Au, 1068° to 1074°, mean 1072°; Cu, 1076° to 1093°, mean 1082°. Often the two methods yield repeatedly the same results. Beyond 1456° extrapolation has been resorted to, based upon the thermo-E.M.F. of a couple which is an almost linear function of the temperature, and the resistances of pure platinum and rhodium; the comparison with the air-thermometer is being continued. Nickel was fused in a magnesia crucible; melting-point 1477° to 1488°, mean 1484°. Palladium was tested by the thermopile-fuse in a special tube. A vacuum could not be applied, as even this tube softened. A reduction of the silicic acid by hydrogen was here clearly observed, a palladium-silicon being formed; finally, concordant results were obtained for air and hydrogen: 1584° to 1593°, mean 1587°. Platinum was fused in a crucible, the thermo-couple being below and covered by a layer of magnesia. As the magnesia is a poor conductor of heat, the couple-fuse had to be applied, the wires reaching into an inverted crucible, partly packed with magnesia; the mean melting-point is 1780°. Violle extrapolates beyond 1200°, Barus beyond 1050°; others are not referred to.

Delicate resistance-measurements are made in the following way:—Two circuits, one containing one accumulator-cell, the other two, are bridged by two wires α and β; β contains the galvanometer, and if there is no current in β, there can be none in α. One of the intercepted parts formed the resistance to be determined. By this method the influences of hydrogen and silica on platinum wires, heated within the tube of a Deville furnace, were tested. The hydrogen was made electrolytically or generated from zinc, and dried. Heating in hydrogen raised the resistance from 0·239 to 0·262 ohm. Palladium and rhodium behave similarly, and their temperature-coefficients vary likewise. The resistance-curves of two pure platinum wires, moreover, began to deviate from one another above 1000°, and slight impurities had a very marked effect. The resistance-curve of rhodium is roughly a straight line, in reality a long drawn-out S. That of platinum resembles a straight line more nearly than Callendar assumes; the authors do not think that the resistances at high temperatures can be derived from observations at 0°, 100°, 440°, although they grant that some of Heycock and Neville's melting-points agree with their own.

The chemical action of hydrogen documented itself in another manner. Hecht has made tubes of a very refractory clay. The tubes are porous, and glazed outside; a glazing inside is not permissive, as it decomposes at high temperatures. From two such concentric tubes hydrogen seemed to disappear; there was no escape, however, but chemical action. When the clay is compressed, the tubes are less porous, but they shrink considerably until used in the Deville furnace. A Pintsch water-gas stove has also been employed for baking them. The authors sum up against resistance-pyrometers, against Callendar's formula, in favour of thermo-couples. They have had constructed by Keiser and Schmidt, of Berlin, a special D'Arsonval galvanometer with two adjustable scales, to read off simultaneously resistance and temperature, and to set the zero to any degree, if ice-cooling is not resorted to.

H. B.

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772. *Cooling Action of Currents of Air.* **A. Oberbeck.** (Wied. Ann. 56. pp. 397–411, 1895.)—The author describes experiments to determine the lowering of temperature of a hot wire exposed to a current of air, and the amount of heat given off. The wire, heated electrically, was placed in the current from a fan; the speed of the air was measured by an anemometer, and the temperature by the resistance of the wire. The wires used were 0·05 and 0·1 mm. diameter. The latter showed a fall of temperature of about 100° to 150° in a current of 1·46 m. per sec., and two to three times as much in one of 4·34 m. The heat carried off by the air (apart from radiation) was, for the slower current, about proportional to the temperature of the wire.

After the experimental numbers follows an attempt at the theory. Replacing the round wire with a square one, with one face parallel to the direction of the air-current, the author calculates the distribution of temperature, and finds the quantity of heat per second and per cm. of wire $=\theta v\rho c/\alpha$, where θ is the excess of temperature of the wire, v=velocity, ρ=density, c=sp. heat of the air. α is a constant; and on the further assumption that the particles of air on leaving the wire have acquired its temperature, α means the thickness of the layer of air required to carry off the heat. For a wire of 0·005 cm. it is 0·003 cm., and for one of 0·01 cm. it is 0·004 cm.

R. A. L.

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773. *Determination of Ratio of the Specific Heats of Air.* **G. Maneuvrier.** (Ann. Chim. et Phys. 6. pp. 321–381, 1895.)—This is the complete paper of which the notice in C. R. has already been abstracted (No. 575, p. 348), and exhibits his method in great detail.

R. E. B.

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774. *Thermal Properties of Vapours.* **A. Battelli.** (N. Cim. 4. 2, pp. 97–115, 1895.)—This portion deals with the density of ether, carbon bisulphide, and the liquid alcohols under the pressure of their own saturated vapours. Two methods were used. In the

first method the densities were determined by a dilatometer filled almost entirely with the pure liquid. The liquid was boiled, and then the point of the tube was sealed at the blowpipe, so that only a small portion of the dilatometer contained vapour. It was then weighed to obtain the density. For higher temperatures the liquid was boiled, the tube broken and sealed again, and again weighed. The weight of the glass and liquid removed was taken into account in determining the density. In the second method the dilatometer was attached to a graduated vertical tube leading downwards into another vessel filled with mercury and subject to pressure from a Cailletet pump. The dilatometer was surrounded by a stove, and could be given any required temperature. When this was attained, the mercury was forced upwards through the graduated tube till the top of the liquid reached the upper neck of the dilatometer, and the latter was sealed. The height of the mercury indicated the pressure. Tables are given of the densities of the three liquids investigated, from $-15°$ C. to 195° C. in the case of ether, up to 268° C. in the case of CS_2 and 240° C. in the case of alcohol, from 5 to 5 degrees. The author then endeavours to find a formula for these densities, but so far without success. Clausius' formula, even in its new form, does not lend itself exactly to the representation of the relations between volume, pressure, and temperature.

E. E. F.

ELECTRICITY.

775. *Effects of "Distributed Capacity" in Wire Coils.* **A. S. Kimball.** (El. World, 26. pp. 39–41, 1895.)—Several experiments are described which illustrate the effects of distributed capacity in wire coils. A coil is wound of No. 36 german-silver wire, the winding being non-inductive, and is saturated with paraffin. The resistance of the coil is 100,000 ohms. Equal direct and alternating potential-differences are successively applied to the terminals of the coil, and the corresponding currents are observed. The voltage is measured with a Kelvin electrostatic voltmeter, and the current by means of an electro-dynamometer. The alternating current is always found to be greater than the direct current in the ratio of 3 to 1. This is due to the "capacity current" which appears on using alternating potential-differences. On taking observations on the phase of the alternating current relative to the applied potential-difference, it is found that capacity causes the former to be about 20 degrees in advance of the latter. Other experiments are described which show that distributed capacity in coils of wire is a possibility which must be taken into account even in some of the ordinary electro-technical measurements. W. G. R.

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776. *Velocity of Electric Waves.* **J. Trowbridge** and **W. Duane.** (Am. J. Sc. 50. pp. 104–109, 1895.)—This paper records a continuation of the work an abstract of which appeared in Phys. Soc. Abstracts, No. 473, June 1895. A somewhat different arrangement of the apparatus was here finally adopted after a long series of trials. For the spark-gap terminals in the secondary circuit, after trying tin, aluminium, magnesium, fuse metal, &c., cadmium was approved as productive of the best sparks for photographic purposes. The following are the results of the measurements with the improved apparatus :—

No. of Revolutions of Mirror per second.	Distance in cm. between successive points on the photographic plate.	Time of oscillation in seconds.	Length of wave in cm.	Velocity of waves in cm. per second.
70·8	0·05028	$1·869\times10^{-7}$	5670	$3·030\times10^{10}$
73·7	0·05247	$1·877\times10^{-7}$	5670	$3·021\times10^{10}$
75·2	0·05536	$1·940\times10^{-7}$	5670	$2·923\times10^{10}$
69·5	0·05002	$1·897\times10^{-7}$	5690	$3·000\times10^{10}$
68·9	0·04900	$1·876\times10^{-7}$	5690	$3·034\times10^{10}$
69·0	0·04974	$1·899\times10^{-7}$	5690	$2·996\times10^{10}$
71·2	0·05075	$1·879\times10^{-7}$	5660	$3·013\times10^{10}$

Whence the mean value of the velocity is $3·0024\times10^{10}$ cm. per second. E. H. B.

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777. *The Sensibility of Galvanometers.* **W. M. Stine.** (El. World, 26. pp. 38–39, 1895.)—There is nothing new in this paper. The author insists that due care has not been taken to define completely the sensibility of the galvanometers. Attention is drawn to the fact that in estimating sensibility, account should be taken of the controlling field, the periodic time of the needle, and the correction for damping. The article especially calls attention to the proper rating of astatic and non-astatic galvanometers, yet the author fails to notice that the sensibility of an astatic galvanometer really depends upon the degree of astaticism attained. W. G. R.

778. *A Vibration Galvanometer.* **H. Rubens.** (Wied. Ann. 56. pp. 27–41, 1895.)—The author, after comparing the several methods of measuring oscillatory currents, gives preference to Wien's Optical Telephone as being by far the most sensitive. The great disadvantage possessed by this instrument is that it can be used only for frequencies corresponding to that of its diaphragm within one or two per cent. The author's vibration-galvanometer, acting on the same principle, is rather more sensitive than the optical telephone, and is made responsive to widely different frequencies, by means of a simple adjustment. Two horseshoe-magnets, with their pole-pieces surrounded by coils, act on the ends of a number of parallel strips of iron; the system of strips is suspended by a torsion wire, capable of being clamped at different points, so as to vary its period of oscillation. The amplitude of oscillation is measured, as in the optical telephone, by a mirror attached to the strips. From a table of results given by the author, the instrument appears to give one millimetre deflection for 10^{-8} ampere and to give readings accurately proportional to the current. G. H. Ba.

779. *Determination of Self-Induction Coefficients by Alternating Currents.* **F. Koláček.** (Wied. Ann. 55. pp. 604–609, 1895.)—If a closed coil is placed in a periodic magnetic field so that the flow of induction through it $=P_0 \cos nt$, and the coordinates of the coil are ϕ, ψ . . . the corresponding average forces are :—

$$\bar{\Phi} = -\frac{\partial}{\partial\phi}\left(P_0^{\,2}\right)\frac{Ln^2}{L^2n^2+w^2},$$

where L is the self-induction and w the resistance. A flat coil of area F placed in the field $H_0 \cos nt$ suffers the greatest force when ϕ the angle between its normal and the direction of the field $=45°$. Then

$$\bar{\Phi} = F^2H^2\frac{Ln^2}{L^2n^2+w^2}.$$

The coil may be hung bifilarly and the couple Φ measured. No experimental details are given. R. A. L.

780. *Methods for Studying Currents in Open Circuits and Displacement Currents in Dielectrics.* **W. De Nikolaieve.** (J. Phys. 4. pp. 245–254, 1895.)—The mechanical actions accompanying induction in a variable field are here utilized for studying the currents induced in open metallic circuits and in dielectrics. The first experiments have already yielded interesting results. An open metallic circuit or dielectric is made the seat of alternating or varying currents. In order to excite and study these currents, one may place in an alternating magnetic field F_m either (1) a small open coil, (2) an open ring of metal with a condenser of mica plates attached to increase its capacity, or (3) a ring of dielectric. The alternating field F_m induces in the circuit a current i, this in turn produces a secondary alternating field f_m. The electromagnetic actions give rise to a couple tending to deflect the open (or dielectric) circuit. The observation of this deflection of the circuit furnishes the means of studying the currents of which it is the seat. In the first method of experimenting, the open circuit or dielectric ring is suspended between the poles of an electromagnet excited by the current from a Siemens Alternator, it is therefore placed in a field whose vibration is sinusoidal. The paper also gives a second experimental method, treats the subject analytically, and discusses its bearing upon Maxwell's electromagnetic theory.

E. H. B.

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781. *Polarization of Thin Metallic Membranes.* **H. Luggin.** (Wied. Ann. 56. pp. 347–352, 1895.)—When an electrolytic cell is divided into two partitions by a membrane of gold or silver, the resistance is not sensibly increased, and no evolution of gas takes place. On substituting a piece of platinum foil, the resistance increases and gas is rapidly given off. This happens even if there is a hole in the platinum-foil. The author shows that in every case the current finds its way through the pores in the membrane. This was proved by measurements of differences of potential on the two faces of a gold-leaf separating two vessels, one inside the other, forming an electrolytic cell with platinum electrodes. Currents below a milliampere were used. The apparent resistance of the gold leaf, of 38·6 sq. mm. area and 0·0013 mm. thick, was about 770 ohms. With the conductivity of the liquid in question, the total area of the pores traversing the gold-leaf need not exceed $23{\cdot}5 \times 10^{-6}$ sq. mm. in order to account for the apparent conductivity of the membrane. That the "critical current," *i. e.* the current at which evolution of gas commences, is proportional to the conductivity of the liquid, is explained by the necessity of a certain difference of potential to produce electrolysis of water.

E. E. F.

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782. *On the Use of a Ballistic Galvanometer when the Discharge through it is not Instantaneous.* **P. Weiss.** (J. Phys. 4. pp. 420–424, 1895.)—The author investigates the case of two discharges passing through a ballistic galvanometer separated by a

short interval of time. As an instance, he mentions the use of a ballistic galvanometer in comparing two mutual inductions, the electromotive force of one being retarded by the presence of closed secondaries. He gives two proofs, for damped and for undamped oscillations, showing that if the distance travelled by the needle is an infinitely small quantity of the first order, compared with the amplitude, this latter measures the difference between the discharges to an infinitely small quantity of the second order.

G. H. Ba.

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783. *Convenient Demonstration of the Electric Index of Refraction of Liquids.* **P. Drude.** (Wied. Ann. 55. pp. 633–655, 1895.)—When electric waves pass from the air into an insulating liquid, their wave-length is shortened. The ratio of the wave-length in air to that in the liquid is called the *electrical* index of refraction of the liquid. According to theory, this index is the square root of the dielectric constant of the liquid. Hitherto, however, there has been no convenient method of demonstrating this phenomenon to an audience. If one attempts it by the deviation of the waves in air between parabolic mirrors on passing through a prism or on entering a layer of liquid as in optics, then either very large prisms or troughs of liquid are required, or else one must use very small waves and very delicate means of detection. The present author has avoided both alternatives by the adoption of waves along a pair of parallel wires 64 cm. long and 2 cm. apart, which form the secondary or Lecher circuit to a Blondlot exciter. The whole apparatus is kept small, the wave-length in air being 72 cm. For detecting the waves a Zehnder tube is used connected to a gold-leaf electroscope and a Zamboni pile. Upon the parallel wires two movable bridges are also placed to produce the nodes and loops of the electric waves where desired. Near the end, remote from the exciter, the pair of wires is bent so as to dip into the liquid to be experimented upon, which is contained in a trough 18 cm. long. The disposition of things along the secondary when set up for working is then as follows:—Exciter, bridge B_1, Zehnder tube, entrance of the parallel wires into the liquid, bridge B_3, exit of wires from liquid, end of wires. In order to make a determination of the electric refractive index of a liquid, the bridge B_1 is adjusted until the Zehnder tube (midway between it and the liquid) indicates a loop, the bridge B_3 being meanwhile at the point where the wires enter the water. The bridge B_3 is then gradually advanced along the wires in the liquid and its positions noted, which correspond to nodes and loops of the electrical waves in the liquid as indicated by the Zehnder tube which, together with the bridge B_1, remains untouched during this second part of the experiment. The wave-lengths in the air and in the liquid are thus readily demonstrated and determined. The ratio of the two for ordinary tap-water in a preliminary experiment was 9, whence the dielectric constant at once follows. A more exact determination with distilled water gave 8·7 and 76 ± 6 respectively for the same constants. E. H. B.

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784. *Electric Resistivity of Metals in different Dielectrics.* **G. P. Grimaldi** and **G. Platania.** (N. Cim. 4. 2, pp. 39–49, 1895.)—Part 1st. On the Resistance of Copper in Petroleum.—Prof. Sanford, starting from the consideration that current-conduction is a phenomenon of the field, found in 1892 (among other data) that copper is more conductive in petroleum than in air in the ratio of 1·0018 to 1·0000. His apparatus consisted of a copper tube closed at one end, and connected at the other with an axially arranged copper wire. The current ran along the wire and back by the tube. The temperature was measured to tenths of degrees. The tube was made one of the arms of a Wheatstone bridge; and its resistance was measured when the tube contained air or was filled, in succession, with various dielectric liquids. The authors investigated this subject; and then Prof. Carhart's negative results were published. Both Sanford and Carhart worked at varying temperatures; the authors object to this, since the varying temperatures induce resistance-variations greater than the variations under investigation. They use a tube like Sanford's and Carhart's, but twice as wide, and less in length. The authors, instead of using a single such tube, have used two, and balanced them on a bridge when both contained air only; then filling the one with petroleum was found to disturb the balance. Precautions were taken to keep the temperature uniform in all the arms of the bridge. The authors carefully discuss the causes of error:—E.M.F.'s due to mercury-contacts (eliminated by abolishing these); temperature-differences (kept below 0°·005, or else corrected for if not exceeding 0°·04 by means of the data of falling-temperature observations); thermo-electric currents (not found, for the balance was sustained for weeks, and there were no fluctuations); variations of resistance in the respective arms of the bridge due to temperature changes (not found, for these changes would have had to be at least $\frac{1}{20}°$, while the temperatures were observed within $\frac{1}{200}°$); errors of observation (not so, because variations were all in one direction); stretching of the copper tube by the weight of the petroleum (not so, because too small, and if real would have produced not a diminution but an increase of the resistance); conductivity of the petroleum (not so, for this would only account for one-millionth the observed effect). The net result is that copper in petroleum is more conductive than copper in air, in the ratio of 1·00015 to 1·00000; about one-twelfth of Sanford's result. The authors attribute this difference to the want of delicacy in the preceding observers' thermometers (Sanford to $\frac{1}{10}°$; Carhart to $\frac{1}{2}°$), which has complicated their results with variations of resistance due to temperature-changes. A. D.

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785. *Practical Use of the Wheatstone-Kirchhoff Bridge.* **F. Kohlrausch.** (Wied. Ann. 56. pp. 177–184, 1895.)—The author describes a convenient arrangement of the bridge, generally known as the Kohlrausch Bridge, and means for obtaining a sharper minimum of sound in the telephone used with it. Two

bridges of the cylinder form are illustrated, one with a marble and the other with a wooden cylinder. A plug-commutator is provided, which enables two additional resistances to be connected in series with the bridge-wire. These are conveniently each 4·5 times the resistance of the wire, and are joined up, one at each end of the wire for comparing nearly equal resistances, and both at one end for very unequal resistances. By adopting this value, the ratio is deduced without calculation. The author claims an accuracy in the first case of 1 in 25,000, if the position on the bridge wire is exact to one ten-thousandth of the length, *i. e.*, to one-tenth of a division. A method of comparing the bridge-resistances among themselves is given. To compensate for capacity in measuring the conductivity of electrolytes, an adjustable condenser is provided. This is of very simple construction, consisting of tin-foil sheets of varying sizes stuck on a strip of paraffined paper, which is then folded alternately, like a book of views. In order to compensate for the effects of polarisation, the author recommends that a polarization-cell, with the adjustable electrodes described by him in Wied. Ann. 51. 1894, should be joined in series with the comparison-resistance. G. H. Ba.

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786. *Parasitic Electrodes.* **G. Delvalez.** (C. R. 121. pp. 492–494, 1895.)—Products of electrolysis make their appearance upon a parasitic electrode when the latter is immersed in an electrolyte through which a current is passed. As examples may be mentioned:—Platinum in copper sulphate; a steel needle in acidulated water; a drop of mercury in acidulated water or copper sulphate; brass in copper sulphate or in a mixture of acetates of copper and lead. In the latter case electrochemical deposits similar to Nobili's figures are produced. On the side of the parasitic electrode facing the positive electrode the deposit is metallic; on the other side it consists of peroxide of lead and exhibits the colours of thin plates. In an electrolytic cell containing a parasitic electrode, the equipotential surfaces are deformed just as in the case of a conductor placed in a uniform field of force. The flow of electricity across the parasitic electrode is such that the current-density increases as we approach its edges. In certain methods of measurement parasitic electrodes are employed and they become polarised; from this it follows that all the measurements made are affected by a systematic error. D. E. J.

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787. *Simple Demonstration of Hertz' Reflection Experiment.* **V. Biernacki.** (Wied. Ann. 55. pp. 599–603, 1895.)—This method for demonstrating the presence of electric waves is an application to the parabolic mirrors used by Hertz of a glass tube loosely filled with metal filings, which was mentioned by Branly in 1890, and used by Lodge ('The Work of Hertz') and called by him a "coherer." The author claims that his method is simpler than those heretofore adopted, and enables one to show the Hertzian phenomena to an audience without requiring any apparatus beyond

what is at hand in every physical department. The exciter is of a form as used by Hertz, and is in the focal line of the primary mirror. The secondary mirror has its focal line horizontal, and in this line is placed the tube of filings, which is in circuit with a few storage-cells or other battery and a lecture galvanometer or an electric bell. The presence of electric waves is shown by a deflection of the galvanometer (or ringing of the bell) due to the greatly reduced electric resistance of the "coherer" when the waves are incident upon it. The mirrors first used were 90 cm. high, 80 cm. width of opening and 12·5 cm. focal length. The tube of copper filings was 20 cm. long, and 0·5 cm. diam. The mirrors were 12 m. apart. Smaller mirrors of 3 cm. focal length were afterwards used, and with these it was quite easy to demonstrate the rectilinear propagation, reflection from a zinc plate, the transparency of insulators, the opacity of conductors, reflection and transmission at a wire-grating, and the experiments with crossed mirrors. E. H. B.

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788. *Periodic Currents and Conduction.* **J. Tuma.** (Wien. Ber. 104. Part II *a*. 5, pp. 470–484, 1895.)—The conductivity of a wire for periodic currents is compared with its conductivity for direct currents by determining the rate at which heat is developed in the two cases. The standard resistance used for such comparisons has to be so chosen that the current-density is uniform throughout the whole cross-section, at all frequencies, and for all currents; the author adopts a very thin conductor, *i. e.*, a tube with walls of 0·001 mm. formed upon a glass rod by electro-deposition. The conductors to be investigated are connected in series with the standard, one at a time; and the quantities of heat developed simultaneously in the standard resistance and in a particular conductor, respectively, are measured by two Bunsen ice-calorimeters. From the quantities of heat generated per second by the same periodic current, numerical values are obtained for the effective resistance of a conductor in terms of the resistance of the standard. The general arrangement of the electrical part of the apparatus resembles that used in the high-frequency experiments of Tesla. An alternating current, supplied at 100 volts, is transformed up to 10,000 volts. This is conveyed to a spark-gap in a magnetic field, the spark-gap being shunted by a second circuit which includes a glass condenser, an inductive resistance, and the resistances in the two calorimeters. The capacity of the condenser can be made equal to 0·0095, 0·033, or 0·072 micro-farads, and thus different periodicities can be obtained, of 232,900, 124,800, or 84,400 $\sim$ per second, respectively. The author observes that these are not sufficiently rapid to allow the resistance formula, given by Stefan for high periodicities in straight conductors, to be applied with strictness; but he was obliged to limit himself to these low values as he had no adequate means for determining the rates at greater frequencies. Experiments were first made to prove whether the motions of the meniscus in the capillary tubes of the ice-calorimeters

could be taken as proportional to the square of the current. For this purpose direct currents were sent through the two calorimeter-conductors for a known time, and were measured by a Siemens' dynamometer: in this way the reduction-factors for the meniscus readings of the calorimeters were found. A similar comparison then followed with periodic currents at the three different frequencies, and the corresponding effectual resistances were deduced. The *ratio* of these resistances to the resistances measured with direct currents is shown in the form of a table. Other tables are given which exhibit the results of similar tests upon conductors of different thickness; the materials being copper, german-silver, nickel, and iron. In all cases the above ratio increases with the thickness of the conductor and the frequency of the current, and it approaches more and more towards unity as the specific resistance increases. From this last result the author concludes that, through partial conductors conduction takes place in such a way that the current-density is practically uniform at all sections, and he expresses the opinion that this is the explanation of the effect (attributed by the author to d'Arsonval) that currents of very high frequency are comparatively harmless to animal organisms—the conducting path being unrestricted, and therefore of great sectional area. R. A.

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789. *Dielectric Constants.* **J. Lefèvre.** (L'El. 10. pp. 262–264, 1895.)—The specific inductive capacity of a dielectric is measured by comparing the attractive forces between the plates of a condenser by direct weighing—(1) when the space is filled with air; and (2) when a known thickness of dielectric is interposed. An ordinary balance is adapted to the purpose, one of the scale-pans being replaced by a conducting-plate provided with a guard-ring. The distances are measured by a cathetometer. A Ruhmkorff coil is used for charging the plates, with a leyden jar, in the ordinary way; and it is assumed that the difference of potential remains constant during a test. Numerical values are given for several dielectrics, but there is wanting some further account of their constitution and purity; thus a "brown" variety of paraffin wax is mentioned, and among the liquids, "petroleum." In the case of sulphur, paraffin wax, and ebonite, the author examines the change of specific inductive capacity with time; no definite deductions are drawn from the values obtained; the observed differences are thought to result from molecular alteration within the dielectrics. R. A.

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790. *The Determination of large Electrolytic Resistances.* **M. E. Maltby.** (Zschr. phys. Chem. pp. 133–158, 1895.)—This paper describes the practical operation of the method for determining electrolytic resistances proposed by Nernst (Zschr. phys. Chem. (4) 14. p. 622). A Wheatstone bridge is formed of four electrolytic resistances, and the unknown resistance is found by measurements with it alternately in and out of the bridge. Electrostatic

disturbances are compensated by means of two condensers of variable capacity, shunting two adjacent arms of the bridge. Balance was determined in some cases by a telephone, and in others by a Hankel electrometer. The current was rendered intermittent by a wire contact-breaker, arranged to give very rapid and somewhat irregular vibrations. The electrolyte constituting the bridge-resistances was a solution of mannite and boric acid, its very small negative temperature-coefficient being compensated by the addition of a small quantity of potassium chloride. This was contained in U-shaped tubes, having one fixed electrode and two adjustable, one in each limb: widely different resistances were obtained by taking one or the other of these, and by this means resistances of from 100 ohms to 30 megohms could be determined without altering the bridge. For the ratio-arm resistances, a double U-tube of similar construction is employed. The vessel to contain the electrolyte under investigation is a cylinder provided with a thermometer stopper communicating at the bottom by a narrow neck with a small tube at right angles to the cylinder. The electrodes are at each end of this. For badly-conducting electrolytes the tube is enlarged to a spherical shape; electrolytes of low resistance are contained in a capillary tube between two larger tubes. The adjustable condenser consists of two brass plates over a third, the capacity being varied by sliding a glass plate more or less between the plates. The process of comparison is as follows:—The resistances of the ratio arms are adjusted to be equal, by means of a reversing-key, and then the unknown resistance is inserted in series with one of the adjustable resistances, while the other is altered till balance is obtained. The resistance is thus determined in terms of the divisions on the U-tube, which latter was calibrated relatively. Some results are appended showing agreement between individual readings to about $\frac{1}{2}$ per cent., and agreement with Kohlrausch's results to about 1 per cent. G. H. Ba.

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791. *Distribution and Secular Variation of Terrestrial Magnetism.* Nos. II. & III. **L. A. Bauer.** (Amer. J. Sc. 50. pp. 189–204, & 50. pp. 314–325, 1895.) See also Abstract No. 726.—The author attempts to localise the chief causes of asymmetry or distortion in the earth's magnetic field. In the first place, the magnetic elements are calculated on the supposition that the earth is uniformly magnetised about the geographical axis, and the values obtained are compared with the mean values of the elements along the parallels of latitude. The differences obtained between the observed and calculated values are very small considering the great variation which sometimes takes place in the value of an element on going round a parallel of latitude. By drawing the curves of equal differences between the observed and calculated values of the dip for 1885—the author calls such lines isapoclinics—it is found that there are two foci which may be regarded as the seat of the forces which causes the deflection

of the dipping-needle from its normal position. The approximate position of these foci is lat. 20° S., long. 40° W., and lat 5° S. and long. 40° E. It is noticeable that these two secondary poles, as they may be called, which represent the centres of the forces producing the asymmetrical distribution of the earth's magnetism, should be on the same side of the equator and go nearly on it. The principal phenomena of the distribution of terrestrial magnetism can thus be regarded as produced by two rectangular magnetic systems, a polar and an equatorial, the former about five or six times the strength of the latter. The "isapoclinics" have also been calculated for 1780; and in this case the secondary polarisation is again nearly equatorial, but by comparing the curves with those for 1885, it is evident that the secondary magnetic system has been moving along the equator westward. The agonic lines have also during this interval been moving to the westward at a rate such that a complete revolution would be completed in 2000 years. The author concludes Pt. III. by indicating how the movement of the secondary poles may account for the different characters of the curves obtained for the secular motion of the north pole of a freely suspended magnetic needle (see Abstract No. 248). W. W.

CHEMICAL PHYSICS.

792. *Chemical Changes in Magnetic Rocks produced by Heating.* **G. Folgheraiter.** (Rend. Acc. Linc. 4. 2, pp. 78–85, 1895.)—Experiments made on peperino and tufa show that the quantity of magnetite to be extracted from them, when powdered, by a magnet is not increased by previously heating the specimens, although the magnetism is increased. Further, that non-magnetic clay becomes slightly magnetic after heating, and that the powdered peperino, from which magnetite had been extracted, when made into cylinders with the aid of some silicate of potash and water, was not magnetic but became so after heating. The author concludes that non-magnetic iron compounds existing in the rocks are made magnetic by the heating; and that the increase of magnetism observed is partly due to that and partly to orientation of the crystals of magnetite during heating. R. A. L.

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793. *Transition Points determined by the Electrical Method.* **A. E. Baur.** (Zschr. phys. Chem. 18. pp. 180–182, 1895.)—The temperature at which the following reaction occurs:—$Na_2HPO_4 12H_2O \rightleftharpoons Na_2HPO_4 7H_2O + 5H_2O$—was determined by means of the method (depending on the use of a concentration battery) described by E. Cohen and G. Bredig (Zschr. phys. Chem. 14. p. 535, 1894). It was found to lie between 36°·5 and 36°·8 C. The salt $HgI_2 . 2AgI$ was examined in the same way. At approximately 50° C. it changes its colour from yellow to red, owing to its decomposition into its constituents. The decomposition could not be followed in the concentration-cell, however, owing to the reduction of the HgI_2 to Hg_2I_2 by the mercury of the electrodes. T. E.

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794. *Argon and Helium.* **E. A. Hill.** (Am. J. Sc. 50. pp. 359–376, 1895.)—In a previous communication (Abstract No. 480) the difficulty of finding a place in the periodic law for monatomic argon was discussed. The author finds the chemical facts are almost conclusive in favour of the view that argon is diatomic. S. S.

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795. *On the Determination of Argon.* **T. Schlœsing, jun.** (C. R. 121. pp. 525–528, 604–606, 1895.)—Since argon has been discovered, several attempts have been made to decide what *rôle* it plays in the phenomena of animal and vegetable life. G. M'Donald and A. M. Kellas have searched for argon in the constitution of several animals and seeds, but could not find any appreciable quantities of it. As this question is still far from being solved, and is likely to be raised again and again, the author thought that it may be of great practical importance to devise an accurate way of determining the argon in a given volume of atmosphere. It follows from his researches, that the best results are

to be obtained when the volume of air taken for analysis does not exceed one containing about 1·5 litre of nitrogen, and when all the measurements are made over mercury. A special apparatus, the design of which is given in the paper, and seems to be very suitable for this determination, has been constructed by the author, and the argon obtained in a state fit for measurement by eliminating from the air, first the oxygen and the carbonic acid in the usual way, and then by separating the nitrogen in passing the gas, as devised by Rayleigh and Ramsay, through a heated tube filled with magnesium and copper oxide. The argon, after having been freed from the last traces of carbon dioxide and nitrogen, is then measured. It has been found that porcelain or, still better, steel are the most suitable materials for the tube in which the separation of argon from nitrogen is effected. This determination has been repeated several times with very satisfactory and accordant results. To verify the latter, a series of experiments has been made, in which a most exactly measured volume of argon was added to a known volume of chemically obtained pure nitrogen. The loss of argon per 100 parts of argon added amounted to about 0·6. Though such a loss is very admissible considering the complicated manipulations during the determination, a new series of investigations was undertaken with a view of discovering a probable intermediate reaction, which could account for such a loss. In the usual method of determination, the argon comes into contact at a red heat with magnesium, copper, copper oxide, steel, or porcelain and asbestos. The effect of each of these substances was tried upon known volumes of argon; and it was found that, while all the substances above named behave indifferently towards argon, a loss of 0·25 per cent. of argon is effected by the magnesium, if the tube containing it is not heated, that this loss increases to 0·5 per cent. if the tube is heated, and that an additional slight increase is observed if the heating of the tube be prolonged longer than the time necessary for one determination, and if the tension of argon in the apparatus becomes higher. The loss of argon experienced during a series of experiments in which the tube was heated amounted to about 0·68 as a mean, which is in very close accordance with the same loss observed in the former determinations. It can thus be said that the average loss of argon in the present method of its determination is about 0·7 per cent., and a corresponding correction should be made for it. A series of analyses of air taken in Paris at a height of about 12 metres above the earth gave 1·184 vol. of argon in 100 vols. of atmospheric nitrogen (nitrogen + argon), and 0·935 vol. argon in 100 vols. of air containing 79·04 nitrogen. The mean of three samples of air, of which one was taken on a hill in Normandy, another on the top of the Eiffel Tower, and a third in the gallery of an iron mine, was 1·182 per 100 vols. atmospheric nitrogen and 0·934 per 100 vols. of air. These figures show that the quantity of argon present in our atmosphere is, like that of oxygen and nitrogen, very constant. If the above correction of 0·7 per cent. is made, the average figures

would then be 1·192 and 0·941. The determination of argon in gases extracted from different kinds of soil shows that the average quantity of argon is somewhat lower in them than in the atmosphere. Though this can be partly attributed to the solvent action of water, which, as found by Rayleigh and Ramsay, dissolves two and a half times more argon than nitrogen, the fact still remains that rain reaches the earth without having absorbed from the atmosphere all the quantity of argon contained in it. S. R.

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796. *Electrical Conductivity.* **A. E. Baur.** (Zschr. phys. Chem. 18. pp. 183–184, 1895.)—Results are given for some of Thiele's tetrazol compounds, and for the ionic velocity of potassium, rubidium, and calcium from measurements made on their chlorates. The author considers that, owing to the greater differences existing in the solubilities of the chlorates, a greater purity is possible. His results differ slightly from those of Bredig, who worked with the corresponding chlorides. S. S.

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797. *Reversible Reaction.* **F. W. Küster.** (Zschr. phys. Chem. 18. pp. 161–179, 1895.)—The paper contains an account of the course of a reversible reaction of the first order in a homogeneous system. S. S.

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798. *Chemical Equivalents.* **Marqfoy.** (C. R. 121. pp. 591–594, 1895.)—The author believes that the atomic weights of the chemical elements can be represented by multiples or submultiples of the 63 prime numbers occurring in the series of natural whole numbers between 1 and 300. In the table which he gives he shows that the atomic weights of 57 of the elements can be obtained in this way within $\frac{1}{100}$ of their value.

[The paper is itself an abstract by the author, and the concluding remarks are unintelligible. It is also not clear why the multiples used have been selected, and why, among other things, lithium, with the atomic weight 7, should be unclassified.] T. E.

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ERRATA.

For $v^2Kf(v)$, Abstract 129, read $v^2K(v)$.

For $qd_1=(\partial W/\partial v)dv$ (Abstract 290, page 160) read $qdv_1=(\partial W/\partial v)dv$.

For Mont Biret (Abstract 421) *read* Mont Buet.

For Poulkowo (Abstract 423) *read* Poulkovo.

For Thirty rods of 110 mm. length and 27 mm. diameter (Abstract 441) *read* Thirty rods of 100 mm. length and 5 mm. diameter.

For different rates of vibration-polarisation (Abstract 471, page 286) *read* different rates of vibratory polarisation.

For oscillating in character (Abstract 474) *read* oscillatory in character.

In line 3 of Abstract 682, *for* oxygen *read* air, and delete the last sentence on p. 416.

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